Congenital Heart Disease Index Hospitalisation in Scotland; 1990 – 2015.

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Abstract

Significant improvements in the surgical and peri-operative care of infants born with even the most complex of cardiac abnormalities has resulted in improved survival prospects and an increase in the number of individuals with congenital heart disease. It is now estimated that greater than 90% of children born with congenital heart disease will survive well into adulthood.

Few of the surgical repairs for congenital heart disease result in a cure and often lesions are palliated, resulting in patients being subject to a variety of complications later in life and the prospect of further surgical or percutaneous intervention remains high for many. To care for these patients with increasingly complex cardiac anatomy and physiology, both paediatric and adult congenital cardiology care have had to expand and adapt to provide acute inpatient and outpatients services for this ever-growing population of individuals.

While there have been estimates of prevalence and incidence of congenital heart disease, as well as limited analysis of healthcare utilisation on a global stage, the UK has fallen behind in description of hospitalisation in this well-defined cohort of patients. In Scotland we are fortunate enough to have a comprehensive patient record system, whereby demographic, diagnostic and procedural descriptors are recorded uniquely for each inpatient episode which can then be linked over time to further hospitalisations. These records are available for access by clinical teams, in an anonymised format, to enable research and facilitate service development. By utilising the Scottish Morbidity Records I have been able to describe the index hospitalisation of 17 990 individuals with congenital heart disease in Scotland between 1990 and 2015 and report on temporal trends in index hospitalisation with respect to underlying cardiac lesion, sex, age and socio-economic deprivation.

Overall, the number of index hospitalisations and index hospitalisation rate, when indexed to the general population, was observed to increase particularly among all lesions as well as those with transposition of the great arteries with arterial switch, congenital valvular lesions, other lesions and those individuals with congenital cardiac lesions of mild complexity.

There was no difference between the number of males and females who had an index hospitalisation. However, boys had higher levels of index hospitalisations in childhood, and women had higher levels of index hospitalisation compared to men in adulthood. Females were more likely to have an index hospitalisation with lesions of mild complexity, whereas males had a higher incidence of index hospitalisation with lesions of moderate complexity.

There is a rising rate of index hospitalisation among infants (age <1), adults (age ≥16) overall, as well as young adults (ages 20-59), with a decreasing annual index hospitalisation rate among children likely reflecting a higher diagnosis rate of congenital heart disease occurring in infancy.

With respect to socio-economic deprivation, areas in Scotland with increased levels of deprivation had a higher incidence of index hospitalisation which persisted across most congenital lesions and classifications of lesion complexity. Females and paediatric patients experienced higher levels of deprivation compared to males and adults respectively.

These analyses have allowed the trends in index hospitalisation of Scottish patients with congenital heart disease to be studied and reported for the first time and will add substance to the sparse existing literature. They have demonstrated the utility of the Scottish Morbidity Record and will provide a framework for future service planning. One would hope that it acts as a beacon for further research in congenital heart disease in Scotland and elsewhere.

Declaration

I confirm that this thesis is my own work and has been composed solely by me, except in those instances where explicit reference has been made to the contribution of others. It has not been submitted for the fulfilment of any other degree at the University of Glasgow, or any other institution.

This thesis was completed during my employment as a clinical fellow in adult congenital cardiology at the Golden Jubilee National Hospital

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To all the members of the Scottish Adult Congenital Cardiac Service at the Golden Jubilee National Hospital; you should be told more often of the excellent work that you do for the individuals with congenital heart disease in Scotland. I aspire to deliver the levels of care and compassion that you provide for every single person that comes through your doors. You are a wonderful group of individuals and I am proud to say I was part of your team, albeit for only a short time.

To my family and friends, you will never fully know how much your words of wisdom and acts of kindness made this process all the more bearable. You have tolerated my absence at gatherings, holidays and social events as well as my long face following dark days in the library. I look forward to making up for every single one.

This thesis is dedicated to all the patients with congenital heart disease in Scotland; past, present and future.

List of abbreviations & definitions

95% CI	95% confidence intervals
ACHD	adult congenital heart disease
AHP	allied health professionals
ASD	atrial septal defect
APC	annual percentage change
AVSD	atrioventricular septal defect
BAV	bicuspid aortic valve
ccTGA	congenitally corrected transposition of the great arteries
CIS	continuous inpatient stay
CHI	community health index
CHD	congenital heart disease
CMRI	cardiac magnetic resonance imaging
COPD	chronic obstructive pulmonary disease
CPET	cardiopulmonary exercise test
eDRIS	Electronic Data Research and Information Services
GP	General Practitioner
ICD	International Classification of Diseases and Health Related Problems
IE	infective endocarditis

ISD	Information Services Division
MDT	multidisciplinary team
NIS	National Inpatient Sample
NEC	not elsewhere classified
NHS	National Health Service
NSS	National Services Scotland
OPCS	Office of Population Census and Surveys Classification of Surgical Operations and Procedures
PAPVD	partial anomalous pulmonary venous drainage
PBPP	Public Benefit and Privacy Panel
PDA	patent ductus arteriosus
PFO	patent foramen ovale
PHS	Public Health Scotland
PIS	Prescribing Information System
SACCS	Scottish Adult Congenital Cardiac Services
SED	socio-economic deprivation
SIMD	Scottish Index of Multiple Deprivation
SMR	Scottish Morbidity Record
SRV	systemic right ventricle
SVC	superior vena cava

TGA	transposition of the great arteries
TOF	tetralogy of Fallot
USA	United States of America
UK	United Kingdom of Great Britain and Northern Ireland
VSD	ventricular septal defect
WHO	World Health Organisation

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1 Introduction

1.1 Preamble

Congenital heart disease (CHD) is one of the most common groups of congenital malformations worldwide.[1] It is reported to occur in approximately 8 in 1000 live births and in 10% of aborted foetuses.[2-4] The number of adults with CHD currently living in Europe is estimated to be in excess of 1 million[5] and almost 12 million adults and children globally.[6]

One of the greatest success stories in the contemporary era of medicine is the dramatic improvement in the survival prospects of patients born with CHD. In the 1950s, approximately 15% of children born with CHD would survive to adulthood.[7] Since then improvements in diagnostic imaging, surgical repair techniques as well as advances in perioperative medical and anaesthetic care[8] have enabled 90% of patients born with CHD to not only survive childhood but also live well into adulthood.[9] Due to this success the number of adult patients with CHD outnumber children, even amongst those with the most complex CHD lesions.[3]

Most CHD surgery is palliative and should be thought of as a 'repair' and not a life-long 'cure'. This necessitates ongoing specialist care of this group of patients throughout their life not only in childhood, but also throughout adolescence into adulthood.[10] Patients with CHD have a higher level of morbidity and mortality than their peers without CHD.[11] Morbidity and mortality arise not only from the underlying congenital anatomy, but associated factors such as lower exercise capacity, obesity and endocarditis as well as acquired conditions such as coronary artery disease and respiratory ailments. As the number of individuals with CHD survive into adulthood the number of hospitalisations is also increasing.[12]

Thus far, there have been no population estimates or studies of individuals with CHD in Scotland. A better grasp of the epidemiology, health outcomes and hospitalisations of patients with CHD in Scotland will improve our understanding of the current state of CHD and their hospital care in Scotland. Ultimately, this information could (and should) be used as a means of service planning and health care management of this well-defined group.

1.2 Basic Cardiac Structure and Development

The basic structure and function of a 'normally' functioning heart is two pumps in series, with valves to allow only the forward flow of blood, with an intact septum separating oxygen-deplete venous blood returning from the body from that of the oxygen-rich blood returning from the lungs, before it is then propelled around the body via the aorta and systemic arterial circulation. A diagram of the normal heart is shown in Figure 1-1.

Figure 1-1 Diagram of a normal heart[13]

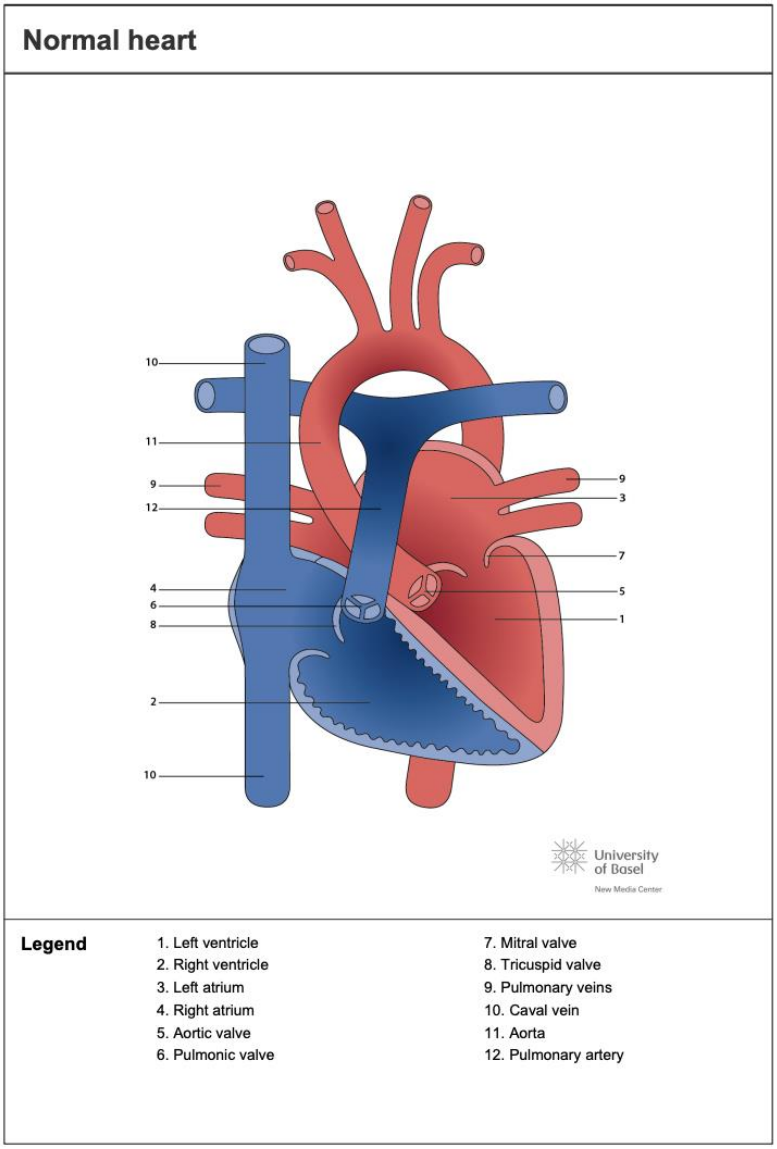


Diagram of the normal heart. The blue area is filled with deoxygenated blood which is pumped by the right ventricle through the pulmonary valve to the lungs where gas exchange occurs. The oxygenated red blood returns to the heart via the pulmonary veins, before being pumped around the body by the left ventricle via the aortic valve. The illustration is taken from http://www.chd-diagrams.com. Illustrations are licensed under Creative Commons Attribution- NonCommercial-NoDerivatives 4.0 International License by the New Media Center of the University of Basel.

Although an in-depth description of the embryological development of the human heart is out with the scope of this thesis, it is certainly worthwhile reviewing some of the critical steps that occur during the formation of the human heart and describing the physiological adaption that is required within the first few hours and days of life, as they can help us understand the consequence of disruption to this process and therefore that of CHD.

The heart and cardiac structures are one of the first organs to differentiate and function in foetal development. The process begins at around 18 days following fertilisation with the formation of two endocardial tubes which fuse to form the tubular heart. The tubular heart differentiates into several distinct regions. From head-to-tail these are called the truncus arteriosus, bulbus cordis, primitive ventricle, primitive atrium and sinus venosus.

The truncus arteriosus will further divide to form the pulmonary and aortic trunks. The bulbus cordis will form the right ventricle. The primitive ventricle will form the left ventricle. The primitive atrium will develop into the anterior portion of both the left and right atrium, as well as their associated appendages and the sinus venosus will form the posterior aspect of the right atrium, including the sinoatrial node and coronary sinus.

During the 4th week of development, the tubular heart undergoes a series of folds and loops. This is then followed by fusion and septation of the chambers within the heart including the atria, ventricle, truncal masses and the ventricular inlet and outlet resembling that of a mature cardiac structure.[14]

Developmental defects in any of these complex processes can occur at any stage, creating one or more cardiac structural abnormalities. Examples of this include, but are not limited to:

- Failure of septation occurring within the common atrial mass (forming an atrial septal defect (ASD)), in the bulbis cordis and the primitive ventricular mass (forming a ventricular septal defect (VSD)) or within the truncus arteriosus (forming a common arterial trunk).

- Deviation of the conventional looping arrangement can cause defects of laterality. For example, deviation from the conventual ‘D’ loop that aids to oppose the ventricular structures causes an ‘L’ looping arrangement, whereby instead of the morphological left ventricle lying to the anatomical left of the morphological right ventricle, the opposite is true i.e. morphological right ventricle lies to the anatomical left of the morphological left ventricle (forming congenitally corrected transposition of the great arteries (ccTGA)). A diagram outlining the cardiac anatomy of ccTGA is shown in Figure 1-2.

Figure 1-2 Diagram illustrating anatomy of ccTGA[13]

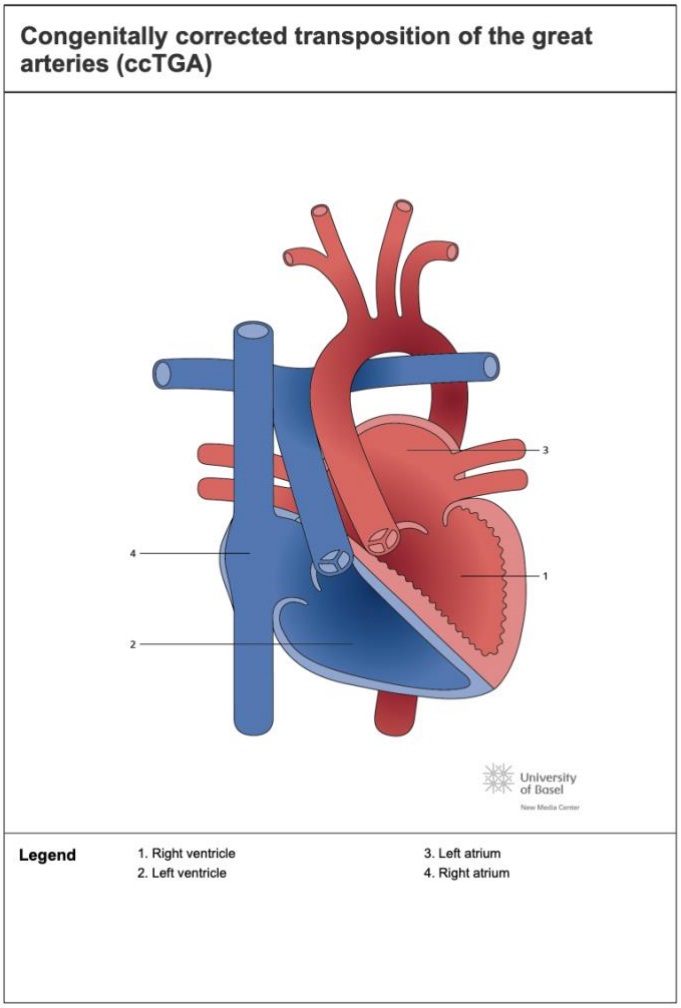


Diagram illustrating the anatomy of ccTGA. ccTGA is characterised by the combination of atrioventricular discordance and ventriculoarterial discordance. The illustration is taken from http://www.chd-diagrams.com. Illustrations are licensed under Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License by the New Media Center of the University of Basel.

- Failure of the formation of the embryological ventricular inlet and outlet segments can form multiple different lesions including double outlet right ventricle, Tetralogy of Fallot (ToF) and double inlet left ventricle.

1.3 CHD Definition

CHD can be defined as a structural anomaly of the heart or intrathoracic great vessels that is present at birth and is, or has, the potential to be of functional significance.[15]

There are several, predominantly vascular, lesions that are not accepted as CHD. These include isolated anomalies of the great systemic veins, such as persistent left sided superior vena cava (SVC). It is generally accepted that isolated anomalies of the systemic arterial aortic arch branches, cardiac arrhythmias not associated with haemodynamic structural malformations, inherited cardiomyopathies and Marfan syndrome (unless associated with another congenital cardiac malformation) are not classified as congenital heart lesions, although in many centres these patients are cared for by clinicians and health care professionals with expertise in CHD.

1.4 CHD Aetiology

The aetiology of CHD is not well understood. Only 20% of cases are able to be attributed to a known cause.[16] Some CHD can associated with several well recognised chromosomal anomalies including trisomy 21, trisomy 18, trisomy 13, Monosomy X and 22q11 deletion.[4] It is estimated that 40-50% of individuals with trisomy 21 will have CHD.[17]

Maternal and environmental risk factors are reported to be associated with CHD in up to 2% of cases. Maternal factors include diabetes, obesity, phenylketonuria, cigarette and alcohol use, rubella infection as well as exposure to certain drugs including thalidomide and retinoic acid. Environmental factors may include exposure to organic solvents.[4,18]

Many causes of CHD are thought to be multifactorial due to a combination of genetic and environmental risk factors. This is seen in families where a

syndromic cause is not found, but there appears to be an increased risk of CHD when one other family member is affected.[4]

1.5 CHD Incidence and Prevalence

CHD incidence is routinely reported as the number of patients with CHD per 1 000 live births. Hoffman and Kaplan estimated in 2002 that the incidence was approximately 10 cases per 1 000 live births.[19] Since their publication there have been several other reports, including registry data and population studies, which have concluded varying incidence of between 3 – 6 cases per 1000 live births.[20-22]

The wider availability of pre-natal ultrasound screening means that a wide range of cardiac malformations are now detected before birth. As a result, parents may be counselled on the option of termination of their pregnancy once a diagnosis of CHD is made and this may therefore affect the birth incidence of CHD. However, with the advent and increased availability of advanced imaging techniques including cardiac computed tomography and cardiac magnetic resonance imaging, as well as improvements in echocardiography, more congenital cardiac lesions are being identified that may have previously not been diagnosed.

The true incidence of CHD can be difficult to define. In general, those CHD lesions with significant haemodynamic effect are easier to identify as they are diagnosed prenatally or present in the first few hours or days of life. These lesions can be grouped together, as lesions of moderate (including ToF and coarctation of the aorta) and great complexity (including, double-outlet ventricle or CHD lesions palliated with the Fontan procedure). These groupings will be described in more detail later in this chapter (Chapter 1.8.2 Diagnosis & Severity of CHD).

Patients with ‘simple’ lesions (such as ASDs and VSD) may not present until the 3rd and 4th decade of life, although by definition their underlying congenital lesion will have been present from birth. At present in Scotland there are limitations in estimating the prevalence of congenital heart disease as there is no registry of patients with CHD and statistics obtained by Information Services

Division (ISD) record diagnoses of inpatient hospitalisations only and not that of patients who attend outpatient services.

There are varying estimates of CHD prevalence depending on the year of study and method of data collection. The USA estimates for the year 2000 there were 3.5 cases per 1 000 adults.[23] Marelli et al.[24] demonstrated an increase in the Canadian prevalence of CHD among adults from 1985 to 2000. In 2000 the prevalence of CHD was 4.09 per 1 000 adults, 11.89 per 1 000 children and 5.78 per 1 000 of the general population. They also found a significant increase in the prevalence of complex CHD as well as an increase in median age of patients with CHD.

1.6 CHD Survival

Children born with complex CHD in the 1950s had a 15% chance of surviving to adulthood. Moons et al.[9] found that 90% of those children born with any CHD lesion between 1990 and 1992 would survive to adulthood (18 years of age); this was an improvement in comparison to previous decades (81%). The same study found no improvement in survival for those aged older than 18, suggesting a similar probability of survival, regardless of what decade they were born in. In contrast, Khairy et al.[25] showed that there was a steady increase in age at death and decreasing mortality in adults with CHD. The same study also demonstrated that there was a shift in mortality away from children and infants towards adults in individuals with CHD.

The leading causes of death in CHD are heart failure, pneumonia, sudden cardiac death and operative mortality at the time of surgical re-intervention.[26] Higher mortality rates are observed in those patients with more complex CHD lesions including Fontan palliation and Eisenmenger syndrome.[27,28] Mortality rates among adults with CHD are higher compared to that of the general population.[10,29,30]

1.7 CHD Morbidity

CHD and the associated surgery and interventions mean that this group of patients are at an increased risk of certain morbidities than the general population. These include:

- Arrhythmia – both ventricular and atrial
- Infective endocarditis (IE)
- Heart Failure
- Pulmonary hypertension

Ventricular and atrial arrhythmias are the most frequent long-term complication in patients with CHD. They can occur immediately in the post-operative period or many years or decades following surgical palliation or repair.[31]

CHD surgery often utilises prostheses, conduits, shunts and many patients have a requirement for devices such as pacemakers and internal cardiac defibrillators. The presence of foreign material, or unrepaired cyanosed CHD increases the risk of IE.[32,33]

As the population of patients with CHD increases and mortality increasingly shifts to adulthood, a new population of elderly patients with CHD is beginning to emerge. This group of patients has higher levels of morbidity, higher hospitalisation rates and higher utilisation of healthcare services compared with younger patients.[34] There is also the emergence of age-related comorbidities such as coronary artery disease and cancer due to external and environmental factors which occur in addition to CHD.[35]

1.8 Classification of CHD

There are several ways that CHD can grouped. One can think of congenital heart disease affecting the paediatric and adult population. One can also group CHD lesions together by structures affected, underlying pathophysiology, or grouping together lesions of similar complexity / severity.

1.8.1 Age

Paediatric cardiologists are the secondary care physicians primarily responsible for caregiving in patients aged 16 and under with CHD. Adults with congenital heart disease may be cared for by general cardiologists, or specialised adult congenital cardiologists. Transition of care from paediatric to adult services is a common theme amongst chronic conditions diagnosed in childhood to ensure safe transfer of care. There is no defined age at which patients should transition from paediatric to adult care, instead the focus is around mental and physical developmental maturity.[36] Nevertheless, roughly speaking patients transfer to adult care around the ages of 16 or 17.

Patients may present at any age with congenital heart disease depending on the severity and haemodynamic significance of the underlying cardiac defect. In paediatric practice, CHD may be diagnosed in pregnancy during pre-natal scanning. Complex lesions with significant haemodynamic significance are usually diagnosed in the neonatal period and may present with a cyanosed or 'blue baby', especially during times of physiological stress such as feeding or crying or intercurrent illness. However, some lesions do not present until later in life. For example, small and moderate sized secundum atrial septal defects may not present until the 2nd – 4th decade of life when patients present with breathlessness or arrhythmia as a result of progressive right ventricular volume overload.

It is estimated that in each year in the UK, 200 cases in every 100 000 live births in the general population will become adults and require their care transitioned for life-long follow up of CHD.[8]

1.8.2 Diagnosis & Severity of CHD

1.8.2.1 The International Statistical Classification of Disease and Related Health Problems

The International Statistical Classification of Diseases and Related Health Problems (ICD) is a medical classification system that is published by the World Health Organisation (WHO). It is currently in its 10th revision (ICD-10), which was adopted for use in Scotland in 1996.[37] ICD-10 allows the definition and

coding of diseases, injuries, signs and symptoms. ICD-10 is used by more than 100 countries worldwide.[38] This allows a standardised approach to classification of disease, therefore enabling international collaboration, comparison and research for epidemiological purposes.

ICD-10 is divided into chapters to allow classification of similar lesions. The CHD lesions are defined together in Chapter XVII: Congenital malformations, deformations and chromosomal abnormalities, under sub-heading: Q20-28 Congenital malformations of the circulatory system. A list of CHD lesions defined by ICD-10 are shown in Table 1-1.

Table 1-1 ICD-10 codes for congenital heart disease

Code	Descriptor
Q20	Congenital malformations of cardiac chambers and connections
Q20.0	Common arterial trunk
Q20.1	Double outlet right ventricle
Q20.2	Double outlet left ventricle
Q20.3	Discordant ventriculoarterial connection
Q20.4	Double inlet ventricle
Q20.5	Discordant atrioventricular connection
Q20.6	Isomerism of atrial appendages
Q20.8	Other congenital malformations of cardiac chambers and connections
Q20.9	Congenital malformation of cardiac chambers and connections, unspecified
Q21	Congenital malformations of cardiac septa
Q21.0	Ventricular septal defect
Q21.1	Atrial septal defect
Q21.2	Atrioventricular septal defect (AVSD)
Q21.3	Tetralogy of Fallot
Q21.4	Aortopulmonary septal defect
Q21.8	Other congenital malformations of the cardiac septa
Q21.9	Congenital malformations of cardiac septum unspecified
Q22	Congenital malformations of pulmonary and tricuspid valves
Q22.0	Pulmonary valve atria
Q22.1	Congenital pulmonary valve stenosis
Q22.2	Congenital pulmonary valve insufficiency
Q23.3	Other congenital malformations of pulmonary valve
Q22.4	Congenital tricuspid stenosis
Q22.5	Ebstein’s anomaly
Q22.6	Hypoplastic right heart syndrome
Q22.8	Other congenital malformations of tricuspid valve
Q22.9	Congenital malformation of tricuspid valve, unspecified
Q23	Congenital malformations of aortic and mitral valves
Q23.0	Congenital stenosis of aortic valve
Q23.1	Congenital insufficiency of aortic valve
Q23.2	Congenital mitral stenosis
Q23.3	Congenital mitral insufficiency
Q23.4	Hypoplastic left heart syndrome
Q23.8	Other congenital malformations of aortic and mitral valves
Q23.9	Congenital malformation of aortic and mitral valves, unspecified
Q24	Other congenital malformations of the heart
Q24.0	Dextrocardia
Q24.1	Laevocardia
Q24.2	Cor triatriatum
Q24.2	Pulmonary infundibular stenosis
Q24.4	Congenital subaortic stenosis
Q24.8	Other specified congenital malformations of heart
Q24.9	Congenital malformations of heart, unspecified
Q25	Congenital malformations of great arteries
Q25.0	Patent ductus arteriosus

Q25.1	Coarctation of aorta
Q25.2	Atresia of aorta
Q25.3	Stenosis of aorta
Q25.4	Other congenital malformations of aorta
Q25.5	Atresia of pulmonary artery
Q25.6	Stenosis of pulmonary artery
Q25.7	Other congenital malformations of pulmonary artery
Q25.8	Other congenital malformation of great arteries
Q25.9	Congenital malformation of great arteries, unspecified
Q26	Congenital malformations of great veins
Q26.2	Total anomalous pulmonary venous connection
Q26.3	Partial anomalous pulmonary venous connection
Q26.4	Anomalous pulmonary venous connection, unspecified

When patients are admitted to hospital, a clinician will describe their diagnoses in the clinical notes. After a discharge letter is generated, this will then be translated into an ICD-10 code by a clinical coder and recorded. The accuracy of the diagnosis recorded depends on the detail of notes recorded by clinicians in the medical notes. Inherently there is some degree of subjectivity in the final ICD coding, as the interpretation of the clinical notes by a coder (and not a clinician) will depend on several factors including expertise, training and experience. This will certainly be the case in each healthcare setting, not to mention regional, national and international variation. This is reflected by the vague lesion descriptions demonstrated above, for example, Q24.9 Congenital malformations of the heart, unspecified.

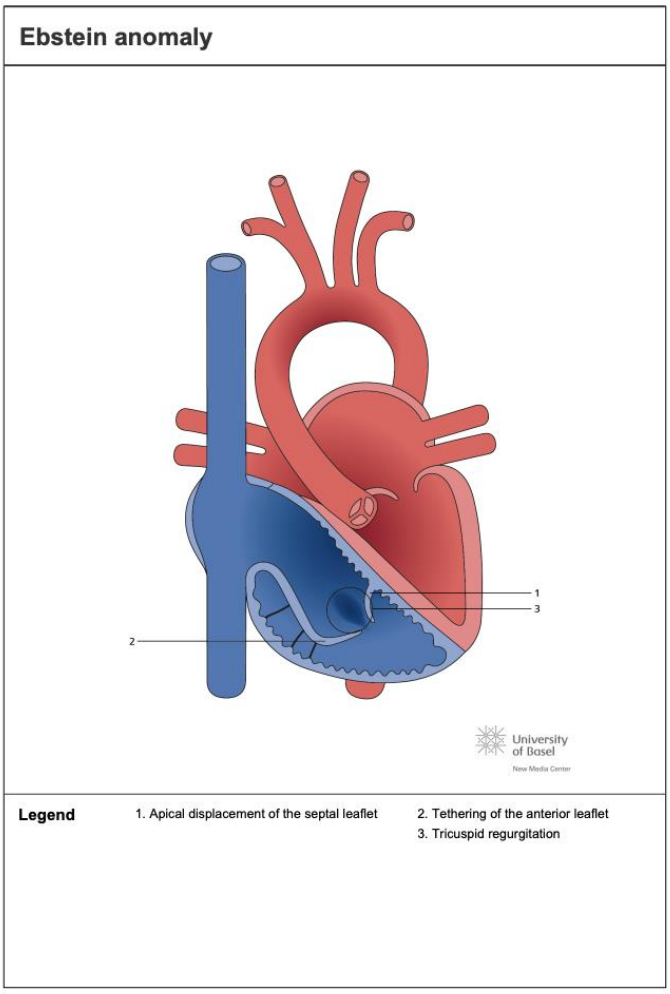
ICD-9 was used prior to the adoption of ICD-10. ICD-10 has almost 68,000 diagnostic descriptors to choose from, compared to approximately 13,000 in ICD-9. This increased number of clinical descriptors allows a greater degree of accuracy in clinical diagnostic coding. The terminology was also refined for use in ICD-10 to reflect current practice. Additionally, ICD-10 incorporated an alphanumeric cataloguing system, compared to only a numeric system in ICD-9 allowing for easier categorisation of disease.[38]

The practice of using ICD for diagnostic coding has limitations and this is easily seen when it is used for CHD as it relates only to the original cardiac anatomy. For example, someone with a previous atrial septal defect that is repaired with no residual shunt would be coded as Z87.74 (Personal history of (corrected) congenital malformations of heart and circulatory system). Another example is of those patients with transposition of the great arteries (TGA) and arterial

switch or patients with Fontan physiology will be coded with their original cardiac anatomy and not their post-surgical anatomy. To accurately describe these patients, one must rely on the combination of diagnostic coding and operative coding. In many conditions, but more so that of CHD, the longer-term aspects of repeat hospitalisation, further surgical intervention as well as morbidity and mortality will significantly depend on the post-operative repair and anatomy. Thus, making the combination of ICD and procedural coding (Office of Population Consensuses and Survey's Classification of Surgical Operations (OPCS)) paramount in describing the individuals with CHD in Scotland from a population-based perspective.

In many cases each patient may have more than one CHD diagnosis as there are commonly associated defects. For example, Ebstein's anomaly with an atrial septal defect. It is common practice for the lesion with the most significant haemodynamic complexity to be considered the underlying CHD lesion and for the case described above this would be Ebstein's anomaly. A diagram illustrating Ebstein's anomaly is shown in Figure 1-3.

Figure 1-3 Diagram illustrating Ebstein's anomaly[13]



The diagram describes the anatomy of Ebstein's anomaly with apical displacement of the septal leaflet of the tricuspid valve and tethering of the anterior leaflet of the tricuspid valve with resultant tricuspid regurgitation. The illustration taken from http://www.chd-diagrams.com. Illustrations are licensed under Creative Commons Attribution- NonCommercial-NoDerivatives 4.0 International License by the New Media Center of the University of Basel.

1.8.2.2 Office of Population Censuses and Surveys' Classification of Surgical Operations

Coding and classification of operations, procedures and interventions utilises a separate system called OPCS. This is currently in its 4th edition (OPCS-4). The primary chapters that are of relevance for the purpose of this thesis are

- Chapter K – Heart
- Chapter L – Arteries and Veins

OPCS has been in use in Scotland since its introduction in the 1980s and is periodically updated to include new and innovative procedures.[37] The OPCS includes descriptors of both open procedures such as cardiac surgery, but also transluminal procedures including percutaneous coronary intervention. The transluminal procedures are a relatively recent addition and most accurately have been included in the version 4.3 (2006) onwards.

1.8.3 Severity & Complexity

The Bethesda classification of CHD which was outlined by Warnes et al.[23] at a 2001 congress assists in classification of lesions but also to helps to stratify lesions in terms of complexity of mild, moderate and great. Part of their primary aim to stratify diagnoses by severity is to allow recommendations to be made on frequency and location of follow-up of patients within an outpatient setting.[23] The lesions in each severity category are described in Table 1-2.

Table 1-2 Bethesda classification of congenital cardiac conditions[23]

Complexity	CHD Diagnosis
Mild	***Native Disease:*** Isolated congenital aortic valve disease Isolated congenital mitral valve disease Isolated patent foramen ovale or small atrial septal defect Isolated small ventricular septal defect (no associated lesions) Mild pulmonic stenosis ***Repaired Conditions:*** Previously ligated or occluded ductus arteriosus Repaired secundum or sinus venousus atrial septal defect (ASD) without residua Repaired ventricular septal defect (VSD) without residua
Moderate	Aorta – left ventricular fistulae Anomalous pulmonary venous drainage, partial or total Atrioventricular canal defect (partial or complete) Coarctation of the aorta Ebstein's anomaly Infundibular right ventricular outflow tract obstruction of significance Ostium primum atrial septal defect Patent ductus arteriosus (PDA) (not closed) Pulmonary valve regurgitation (moderate to severe) Pulmonic valve stenosis (moderate to severe) Sinus of Valsalva fistula / aneurysm Sinus venosis atrial septal defect Subvalvar or supravalvar aortic stenosis Tetralogy of Fallot (ToF) Ventricular septal defect with associated defect(s) Absent valve or valves Aortic regurgitation Coarctation of the aorta Mitral disease Right ventricular outflow tract obstruction Straddling tricuspid or mitral valve Subaortic stenosis
Severe / Great Complexity	Conduits, valved or non-valved Cyanotic congenital heart disease (all forms) Double-outlet ventricle Eisenmenger syndrome Fontan procedure/palliation Mitral atresia Single ventricle (also called double inlet or outlet, common or primitive) Pulmonary atresia (all forms) Pulmonary hypertension Transposition of the great arteries Truncus arteriosus Heterotaxy syndromes

This is intended to be used as a framework for healthcare professionals. Many conditions may reflect a spectrum of disease which a patient may progress through. For example; a patent ductus arteriosus (not closed) may be small,

silent and haemodynamically insignificant (mild) or may be large enough for patients to develop Eisenmenger syndrome (great complexity).

This severity framework was also devised to allow clinicians to determine the location and frequency of review of patients with CHD. Those patients with lesions of mild complexity could be followed up with patients in a general cardiology environment, whereas those patients with lesions of moderate and great complexity should be followed up in a specialised CHD service with regular review and functional assessments as required.

1.8.4 Pathophysiology

Other means of classification of CHD are to group together similar lesions depending on the underlying cardiac physiology.[39] Using this methodology, CHD lesions could be classified under 5 different groups:

1. CHD with increased pulmonary blood flow (patients with septal defects, without obstruction to pulmonary blood flow and therefore left-to-right shunt)

2. CHD with decreased pulmonary blood flow (patients with septal defects with obstruction to pulmonary blood flow and therefore right-to-left shunts)

3. CHD with obstruction to blood progression and no septal defects i.e. No shunts

4. CHD so severe as to incompatible with postnatal blood circulation

5. CHD silent until adult age

This is however, not a widely accepted or particularly clinically helpful method of categorisation and will not be used as a means of classification or grouping for the purpose of this thesis.

1.8.5 Anatomic and Physiological Classification

An alternative classification system that includes both the anatomic complexity and the current physiological state (AP classification) of the patient was proposed by the 2018 American Heart Association / American College of Cardiology guidelines for the management of adults with CHD.[40] This system was developed in recognition that the severity of CHD is determined by factors including the native cardiac anatomy, the nature of surgical repair(s) and the current physiology.

The anatomic variables used in this classification system are similar to those described by Warnes et al.[23] in the Bethesda classification which have been described in previously (Chapter 1.8.3). These anatomical variables are assigned a numerical value; Class I for simple (or mild) complexity, Class II for moderate and Class III for great complexity.

The physiological variables are assigned an alphabetical value to represent the current physiological state which range from A – D; with A representing mild or no physiological dysfunction and D representing significant or severe physiological dysfunction. The values and physiological state descriptors are shown in Table 1-3.

Table 1-3 Physiological variables and state in the AP classification of ACHD[40]

Physiological state	Physiological Variables
A	New York Heart Association Functional Class I symptoms No haemodynamic or anatomic sequelae No arrhythmia Normal exercise capacity Normal renal / hepatic / pulmonary
B	New York Heart Association Functional Class II symptoms Mild haemodynamic sequelae (mild aortic enlargement, mild ventricular enlargement, mild ventricular dysfunction) Mild valvular disease Trivial or small shunt (not haemodynamically significant) Arrhythmia not requiring treatment Abnormal objective cardiac limitation to exercise
C	New York Heart Association Functional Class III symptoms Significant (moderate or greater) valvular disease; moderate or greater ventricular dysfunction (systemic, pulmonic or both) Moderate aortic enlargement

C (cont.)	Venous or arterial stenosis Mild or moderate hypoxaemia / cyanosis Haemodynamically significant shunt Arrhythmias controlled with treatment Pulmonary hypertension (less than severe) End-organ dysfunction responsive to therapy
D	New York Heart Association Functional Class IV symptoms Severe aortic enlargement Arrhythmias refractory to treatment Severe hypoxaemia (almost always associated with cyanosis) Severe pulmonary hypertension Eisenmenger syndrome Refractory end-organ dysfunction

An example of the AP classification system in use would be an individual with repaired Tetralogy of Fallot with no significant pulmonary valve regurgitation, normal ventricular function and no exercise limitation. They would be AP classification IIA. However, if a patient with repaired Tetralogy of Fallot has severe pulmonary regurgitation, ventricular dysfunction and exercise limitation, they would be AP classification IIC. This system allows longitudinal assessment of individuals with the physiological classification reflective of the patient's current condition.

While the AP classification has obvious strengths over the Bethesda classification, it requires documentation of the classification by a healthcare professional and/or access to clinical information including the results of diagnostic investigations and details of current functional status. As clinical coding in its current state does not currently allow for these descriptors, the use of the AP classification in describing the severity of CHD will be limited to databases where the specific information is recorded, or when individual case note review is possible.

1.9 CHD Hospitalisation

Hospitalisation rates are increasing for both planned and unscheduled care, reflecting an increase in healthcare utilisation for this population.[41]

General acute admissions to hospital are split into two broad themes:

- Inpatient – whereby a patient occupies a bed in a hospital and remains overnight

- Day case – whereby a patient makes a planned attendance to a healthcare facility for clinical care, sees a doctor or nurse and requires the use of a bed and/or trolley. The patient is not expected to and does not remain in hospital overnight

Inpatient admissions can be further broken down into:

- Elective – or planned admissions. A patient has been given a date to come into hospital for an investigation and/or procedure

- Transfer – A patient will have already been admitted to hospital and is either transferred between specialties and/or hospital and will be part of the same continuous stay in hospital

- Emergency Admission –A patient is admitted to hospital due to clinical reasons, at the first possible opportunity. They will be seen by a doctor or other health care practitioner and may be admitted to hospital, generally through an Emergency Department

Hospitalisations for CHD can be described as an index hospitalisation for CHD which refers to the first instance in the dataset that a patient is discharged from hospital with a distinct diagnosis. In contrast, total hospitalisations for CHD (which includes the index hospitalisation and subsequent rehospitalisation for CHD), can be used to describe the total burden of hospitalisations. Moreover, all or all-cause hospitalisations can be used as a term to describe any instance that a patient is hospitalised for any diagnosis (including CHD). Using index hospitalisation one can describe the demographics of the individual at the point

at which a diagnosis of CHD is described for the first time. This can be used as a surrogate for the reporting of incidence and consequently estimating prevalence. It also allows analysis of temporal variations in index hospitalisation of patients with CHD with respect to underlying patient characteristics including sex, age and socio-economic deprivation (SED). One further advantage of defining an index hospitalisation is that it marks a point in the patient journey that time can be measured from allowing further survival analyses to be conducted.

Using index hospitalisation to identify this study population has potential disadvantages. Individuals with CHD will require both a hospitalisation and a diagnostic or procedural code describing CHD to be recognised as an index CHD hospitalisation. Those individuals who have never been hospitalised, or who have a hospitalisation where an ICD or OPCS code does not contain a CHD diagnosis (despite having CHD), would not be included. By analysing index hospitalisations only, the true burden of CHD healthcare utilisation will likely be underestimated as individuals with CHD may require more than one hospitalisation over the study period. Other points of access to secondary healthcare would also not be accounted for by using index hospitalisation, including emergency department and outpatient services attendance.

As I aim to describe the rates of first hospitalisations for CHD in the dataset, I will refer to index hospitalisations throughout the thesis.

The number of patients with CHD requiring hospitalisation is on the increase. This has been reported worldwide and described in England, Netherlands, USA and Australia[41–44] by use of registries, databases and national records. Hospitalisation rates are at least twice that of the general population, and the difference is more pronounced in the older age groups.[42]

Whilst there is already information available from Public Health Scotland (PHS) to demonstrate the increasing trend in annual hospitalisations for all patients[45] there is no specific data on the hospitalisation or hospitalisation rates of patients with CHD. It would seem logical to assume that if the number of CHD hospitalisations in comparable healthcare settings throughout the world are increasing, then so should hospitalisation rates of patients with CHD in Scotland.

1.10 Hospitalisation in Other Chronic Illnesses in Scotland

Hospitalisation rates of common chronic medical conditions in Scotland are published by the Scottish Government. It is helpful to understand temporal changes in hospitalisation rates reported for other medical conditions to allow a more robust understanding of the temporal changes in CHD hospitalisation.

1.10.1 Cardiac Hospitalisations

The Scottish Government use the term 'coronary heart disease' to include diagnoses of angina, myocardial infarction and heart failure. During the period 2008–2018, there was a 12.5% decrease in the age and sex adjusted hospitalisation rate from 1 091 to 955 per 100 000 population for individuals with a primary diagnosis of coronary heart disease.[46] Myocardial infarction hospitalisation rates within this period increased by 15.9% from 425 to 493 per 100 000 of the population. This increase in hospitalisation rate is likely driven by the contemporary use of high-sensitivity troponin assays, meaning that some cases that may have been diagnosed as angina or another similar condition would now be classified as a myocardial infarction. Heart failure hospitalisation rates within the same period increased by 23.3% from 276 to 341 per 100 000 of the population. Angina hospitalisations have fallen substantially within the period 2008-2018, with a reduction in the hospitalisation rates from 278 to 122 (56.1%) per 100 000 of the population.[46]

Scottish atrial fibrillation hospitalisation rates increased from 156 to 180 per 100 000 of the population during the period 2008-2018. This represents at 14.6% increase.

1.10.2 Non-cardiac Hospitalisation

Prior to 2014 these hospitalisation statistics were reported as the number of consultant episodes per year, where an episode is defined by a hospital stay under the care of one consultant. A patient is likely to have care delivered by more than one consultant during their inpatient stay as they are transferred between the emergency department or acute receiving unit to a place of continuing care. Thus, a hospitalisation may have numerous episodes. It is only

since 2014 where long-term condition hospitalisation statistics are reported as the number of hospital stays (with the exception of stroke). Hospitalisation rates are reported per 100 000 of the population. Those long-term conditions with reported hospitalisations rates include:

a) *Stroke* – increase in hospitalisation rate from 559 to 651 (2008–2018), representing a 16.5% increase[47]

b) *Arthritis* – decrease in the hospitalisation rate from 838 to 692 (2014–2018), representing a 17.4% decrease[48]

c) *Asthma* – no overall change in the hospitalisation rate (2014-2018).[48]

d) *Back Problems* – decrease in the hospitalisation rate from 285 to 253 (2014-2018), representing a 11.2% decrease[48]

e) *Chronic Obstructive Pulmonary Disease (COPD)* – decrease in the hospitalisation rate from 351 to 331 (2014–2018), representing a 5.7% decrease[48]

f) *Diabetes Mellitus* – decrease in the hospitalisation rate from 106 to 104 (2014–2018), representing a 1.6% decrease[48]

g) *Inflammatory Bowel Disease* – increase in the hospitalisation rate from 161 to 235 (2014–2018), representing a 46% increase[48]

1.11 Structure of Health Care in the United Kingdom and Scotland

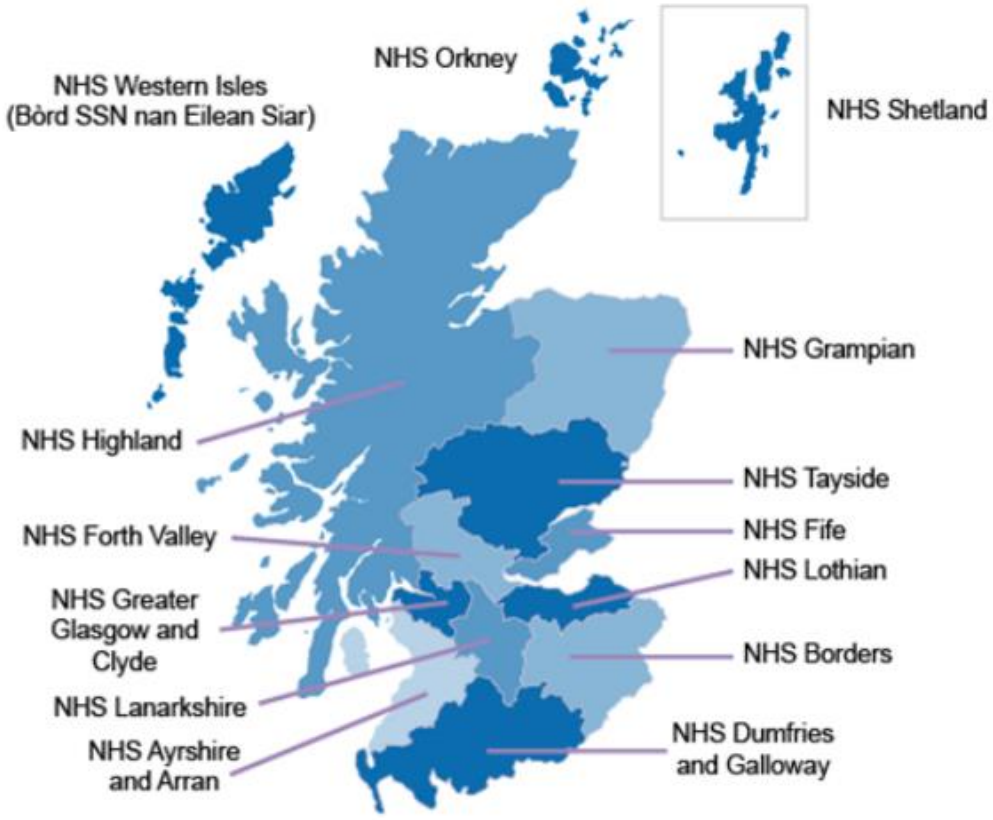
The National Health Service (NHS) was established in Scotland in 1948 and provides health care for all, free at the point of care and access based on need. The Scottish Parliament was established in 1999, and Health legislation was largely then devolved to Holyrood.[49]

The Scottish population in 2016 was estimated at 5,404,700.[50] The budget for healthcare in Scotland was £13 billion in the financial year of 2016/17 (35% of the total Scottish Government spending). Healthcare is managed and delivered

by local Health Boards which are responsible for healthcare services in their geographical area.

There are 14 geographical health boards and 8 ‘special’ Health Boards. The geographical area and location of each territorial health board is demonstrated in Figure 1-4.

Figure 1-4 Geographical area covered by individual Health Boards in Scotland



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Map of Scotland with the individual territories serviced by each Health Boards labelled.

The central belt in Scotland is where the greatest proportion of the population is centred. The three most populous health boards are Greater Glasgow and Clyde, Lothian and Lanarkshire and reflects the largest and most densely populated areas

1.11.1 CHD Care in Scotland

The ‘special’ Health Boards include bodies such as NHS 24, Scottish Ambulance Service and National Services Scotland (NSS). NSS and National Services Division are responsible for commissioning specialist services within Scotland. The Scottish Adult Congenital Cardiology Service (SACCS) is one such service. It is

based in Clydebank in the Golden Jubilee National Hospital. SACCS became operational in 2009 with the main aim to centralise care for adult patients, from all over Scotland, with CHD requiring cardiac surgery and/or percutaneous catheter interventions. The service also provides specialist investigations such as cardiac magnetic resonance imaging (cMRI), cardiac computed tomography (CT) and cardiopulmonary exercise testing (CPET). Weekly clinics provide specialist ACHD outpatient review for those patients with moderate and complex CHD as well as those patients referred for consideration of surgery or intervention. Other clinics include pulmonary arterial hypertension, pre-pregnancy counselling, heart failure and post-intervention clinics.

A hub-and-spoke model exists for outpatient services for adults with CHD In Scotland. Each regional health board, as discussed above, regularly reviews adults with CHD in either general cardiology or stand-alone CHD clinics. Generally, patients with congenital lesions of mild complexity (as defined by the Bethesda classification) are seen in their own health board and not referred to the central CHD services unless there is a need for specialist investigation or there is a concern that the patient may need cardiac surgery or percutaneous intervention. Those patients with moderate and complex lesions will operate under a shared-care framework, whereby the patient will have follow-up within their own health board and will have interval appointments with SACCS for review with specialist investigations. This is the model that is generally accepted and recommended through Europe.[51,52]

Paediatric services are also centralised for children with CHD requiring cardiac surgery and percutaneous intervention. The service is situated in Glasgow, within the Royal Hospital for Children at the Queen Elizabeth University Hospital campus. A similar hub-and-spoke model that exists for adults is also in place for paediatric services with regional outpatient paediatric services in Edinburgh, Aberdeen and Dundee. A multi-disciplinary team (MDT) operates between the two services (adult and paediatric) with a common surgical team.

A combined once weekly MDT meeting takes place with representation from the congenital cardiac surgeons, specialist congenital cardiologists (both SACCS and regional cardiologists) as well as paediatric cardiologists, specialist nurse practitioners, cardiac physiologists and radiologists. Specialist MDT meetings

also convene to discuss complex electrophysiology cases, management of patients with CHD in pregnancy as well as pulmonary hypertension and Fontan associated hepatopathy.

1.11.2 Population Level Data Collection

Scotland is at the forefront of population data collection in relation to access and utilisation of health care. Data is collected centrally and administrated nationally by Information Services Division Scotland (ISD). This collated data can be accessed and utilised by individuals or teams who have demonstrated legitimate reasons for accessing the information to the Public Benefit and Privacy Panel.

Every person in Scotland that is registered with a General Practitioner (GP) has a unique 10-digit numeric code called the Community Health Index (CHI) that is assigned to them. The first 6 digits of this code is based on date of birth (DD/MM/YY), followed by two randomly assigned digits. The 9th digit is always an even number for females and odd number for males. Followed lastly by the 10th digit, which is an arithmetic check digit.[53]

Healthcare data for individual patients are collected as a series of Scottish Morbidity Records (SMR). All general and acute inpatient hospitalisations to a hospital are collated in SMR01. This is an episode-based record relating to non-obstetric and non-psychiatric hospitalisations. Geriatric long-stay patients are also excluded from this.

There are over 1 million SMR01 records generated each year. A record is generated once a patient completes an episode of inpatient or day-case care. An episode may be completed upon:

- Discharge home
- Transfer to another clinician (either in the same hospital or in another healthcare facility
- Transfer to another specialty (either under the same or a different clinician)

- Death[54]

Each discharge from hospital may contain one or several episodes. The hospital stay, from admission to discharge, is known as a continuous inpatient stay (CIS). Here is an example to illustrate this. A 33-year-old man presents to hospital via the ED with chest pain. He is admitted to the acute medical unit, seen by a consultant before being transferred to a medical ward under another clinician and subsequently discharged home. This hospitalisation would comprise of 3 episodes and 1 CIS.

Information that can be collected from each episode includes, but is not limited to:

- Patient identifiable information
- Demographic information
- Date of admission
- Date of discharge
- General clinical information
- Length of stay
- Diagnosis via use of clinical coding and ICD-10 diagnosis (currently)
- Operations / Procedures via use of OPCS-4 (currently).

The primary diagnosis is recorded, with up to five secondary diagnoses also included. The OPCS allows four procedures or operations to be coded in the SMR records.

Through the Scottish Record Linking System, SMR1 can be linked to various other datasets. This is achieved by probability matching methods, thereby allowing linkage of individual hospital records for each patient creating linked patient histories. Other databases that can be linked include:

- SMR00 – Outpatients

- SMR06 – Cancer Registrations
- SMR04 – Mental Health
- Registrar General's Death Records

Quality assurance of the accuracy of the information and clinical coding incorporated into SMR is regularly audited and assessed. The ISD required minimum standard is 90% accuracy at the 3-digit level for diagnostic and procedural coding. During the period of review 2014-2015 of SMR01 data, ISD found that the accuracy for the main condition (ICD diagnosis) was 89% and 94% for the main procedure/operation (OPCS). These findings were consistent with previous assessments carried out in 2010/11 & 2004/06.[55]

SMR has many uses in being able to provide population-level data on a variety of health outcomes. It is always worth appreciating that in the interpretation of any data obtained from this resource, no information is provided on performance status, symptomatology, results of individual investigations and the nuances of CHD and the heterogeneity of the individuals and their underlying CHD lesions.

At present a contemporary, comprehensive national registry of patients with CHD does not exist in Scotland. Therefore, to identify patients with CHD in Scotland one must rely on this accurate diagnostic and procedural coding of patients and identifying them through the data linkage systems described above.

1.12 Measures of Socioeconomic Deprivation

There are several methods of measuring relative levels of SED that are routinely used within Scotland.

1.12.1 Carstairs and Morris Index

The Carstairs and Morris index (also called the Carstairs index) was developed in the 1980s using the 1981 census data and has been reproduced for both the 2001 and 2011 Census. The index reflects deprivation at postcode level. It also reflects material disadvantage and is comprised of 4 indicators including lack of car ownership, low occupational status, overcrowded households and male unemployment.[56]

The main disadvantage of using this measure of deprivation is that it under reflects true rural deprivation, as car ownership in rural areas can be essential to rural life no matter how poor a household may be. This is particularly relevant for Scotland as it has the lowest population density of any of the home UK nations. The average population density for Scotland is 67 individual/km2, with a minimum of 8/km2 in the Highlands and a maximum of 3 298/km2 in the city of Glasgow.[57]

1.12.2 Scottish Index of Multiple Deprivation

The Scottish Index of Multiple Deprivation (SIMD) is a relative measure of deprivation across small areas, or data zones, throughout Scotland. All zones have roughly the same population. It is the Scottish Government's preferred tool for identifying pockets of deprivation across Scotland. It was introduced in Scotland in 2004 and is currently in its 6th edition.[58]

SIMD combines seven different domains of deprivation. These are income, employment, health, education, geographical access to services, crime and housing. The domains are formulated using a variety of different indicators to form ranks within each domain. Each domain is then combined to form the overall SIMD. Example indicators used in calculating each domain score is found in Table 1-4.

Table 1-4 SIMD domains, indicators and weighting.

Domain	Indicator	Weighting
Employment	Working age recipients of Jobseekers Allowance or Universal Credit	12 (28%)
Income	Number of adults receiving Income support.	12 (28%)

Crime	Recorded crime rates as well as recorded crimes of violence, sexual and drug offences	2 (5%)
Housing	Persons in houses which are overcrowded or without central heating	1 (2%)
Health Domain	Standardised mortality ratio. Hospital stays related to alcohol or drugs. Emergency stays within hospital. Proportion of drugs prescribed for anxiety, depression or psychosis. Low birth weight	6 (14%)
Education	School attendance. Attainment of school leavers. Working age people - with no qualifications. School leavers enrolling in high education.	6 (14%)
Access	Private transport. Travel time to GP, retail centre, petrol station, school and post office. Access to public transport. Digital access	4 (9%)

There are 6 976 data zones across Scotland. Zone 1 is the area that is most deprived, and zone 6 976 is the least deprived area. This gives a relative measure of deprivation of one area to another. The use of these small data zones allows Government and Local Council to identify small pockets of relative deprivation and focus policy or resources to certain areas more efficiently.[59]

The limitations of SIMD are that it identifies deprived areas and not individuals. As it is a relative comparison of deprivation, it is impossible to say how much more deprived one area is compared to another. There has been criticism of

utilising SIMD for the study of deprivation in health, as health is one of the determining domains in SIMD production. However, the health domain is only weighted to form a small part (approx. 14%) of the overall score. Analyses during the SIMD production have shown that even when the health domain has been removed, the overall SIMD zones are relatively unchanged. SIMD has been approved by the Public Health Institute in health data analysis.[60]

1.13 Summary

By using both ICD and OPCS codes, patients with a diagnosis of CHD can be identified from hospital records using clinical coding. In Scotland there is a national record of all hospital inpatient episodes. These records contain patient demographics as well as describing diagnoses and procedures undertaken during that hospitalisation using ICD and OPCS codes. Temporal changes in hospitalisation of various chronic medical conditions in Scotland have already been reported, however index hospitalisations for CHD in Scotland have yet to be described. In the next Chapter I will undertake a literature review to assess the available literature reporting CHD hospitalisation trends worldwide.

2 Literature Review

2.1 Introduction

The care of patients with CHD has become a significant cardiac speciality in recent decades due to the success and improvements in operative, medical therapeutic and diagnostic care. Some of these patients will not have had any surgical intervention, either due to lack of necessity of surgery or because surgical repair is (or was) not feasible. As one would expect, palliative repairs imply that although an intervention has been carried out, it is not curative and ultimately further surgical or percutaneous procedures are likely. Even those patients with CHD lesions that have had surgical repairs will require life-long cardiac follow-up.

In Scotland, without a regional or national registry, our perception of CHD burden is based on assumption and personal reports of experience, workload and outpatient clinic waiting lists combined with estimates of expected incidence and prevalence rates from published studies of similar populations.

In this Chapter, I review the current available literature describing CHD hospitalisations. Where data is available, I report hospitalisations for individual lesions as well as by lesion complexity. Hospitalisations by sex is also reported.

2.2 Search Strategy

I performed a systematic search of the Ovid MEDLINE and Embase databases from inception to November 2020 to identify all articles relating to hospitalisations of patients with CHD.

The eligibility criteria were defined prior to any literature search and are outlined as follows:

a) Have a diagnosis of congenital heart disease, which includes any of the following: ASD, PDA, VSD, AVSD, ToF, coarctation of the aorta, Ebstein's anomaly, transposition of the great arteries, systemic right ventricle and single ventricle / Fontan circulations

b) Must be hospitalisations and/or hospital discharges and not only emergency department or outpatient attendance

c) Not refer to readmission to hospital following any operative or interventional procedure

d) Not specific hospitalisations due to a new or existing co-morbidity, such as decompensated heart failure, arrhythmia or infective endocarditis

e) Must be in English

A title and abstract search of the following terms was used: “Congenital heart”, “adult congenital heart”, “atrial septal defect”, “ASD”, “patent ductus arteriosus”, “PDA”, “ventricular septal defect”, “VSD”, “atrioventricular septal defect”, “AVSD”, “tetralogy of Fallot”, “transposition of the great arteries”, “TGA”, “congenitally corrected transposition of the great arteries”, “ccTGA”, “systemic right ventricle”, “Fontan”. These were combined with terms “hospitalisation”, “hospitalization”, “hospital admission”, “hospital discharge”, “rate”, “utilisation”, “health care”.

All returned titles or abstracts were screened for relevance and those that I decided were appropriate were accepted for full text review to check against the eligibility criteria.

Several studies used the same database to identify patients with CHD hospitalisations which creates a potential for duplication of patients in different studies. Mackie et al.[61] and Islam et al.[62] used the Canadian institute for Health Information Discharge Abstract Database[63] which is a national Canadian database capturing administrative, clinical and demographic information on all hospital discharges. Although there was crossover in terms of study period and population, I included both studies as they have different subsets of baseline population characteristics including sex. Also, Islam et al.[62] investigated not only all hospitalisations, but included index hospitalisation events and for this reason have been included. Several studies[44,64–67] utilise the Nationwide Inpatient Sample (NIS) database which collects information on a sample of hospital discharge nationwide in the USA and weights this to derive regional and

nationwide estimates of clinical and demographic information, as well as healthcare related fees.[68] Although there is crossover the studies that use the NIS, 2 studies[44,69] investigated adult hospitalisations with subsets for lesion complexity there was only a cross over period of 2 years and so were included. 3 studies[65-67] utilising the NIS reported findings of specific lesions groups (septal defects, ToF and Fontan) and so were also included.

No meta-analysis was attempted due to the heterogenous nature of the studies and reporting of the studied populations.

2.3 Results

2.3.1 Search Results and Article Eligibility

Using the terms described above, the initial search of Medline and Embase returned 528 articles. Following exclusion of duplicates, 288 titles and abstracts were screened according to the predetermined inclusion criteria. Those articles that described a non-human cohort were excluded. In total, 39 full texts were reviewed. 21 articles were subsequently excluded where the full text was inaccessible, as were studies that combined hospitalisation with outpatient and emergency department use and those studies that reported on hospitalisation cost and not hospitalisation or rates. 1 article was excluded as it was an editorial. The screening and inclusion process is summarised in Figure 2-1.

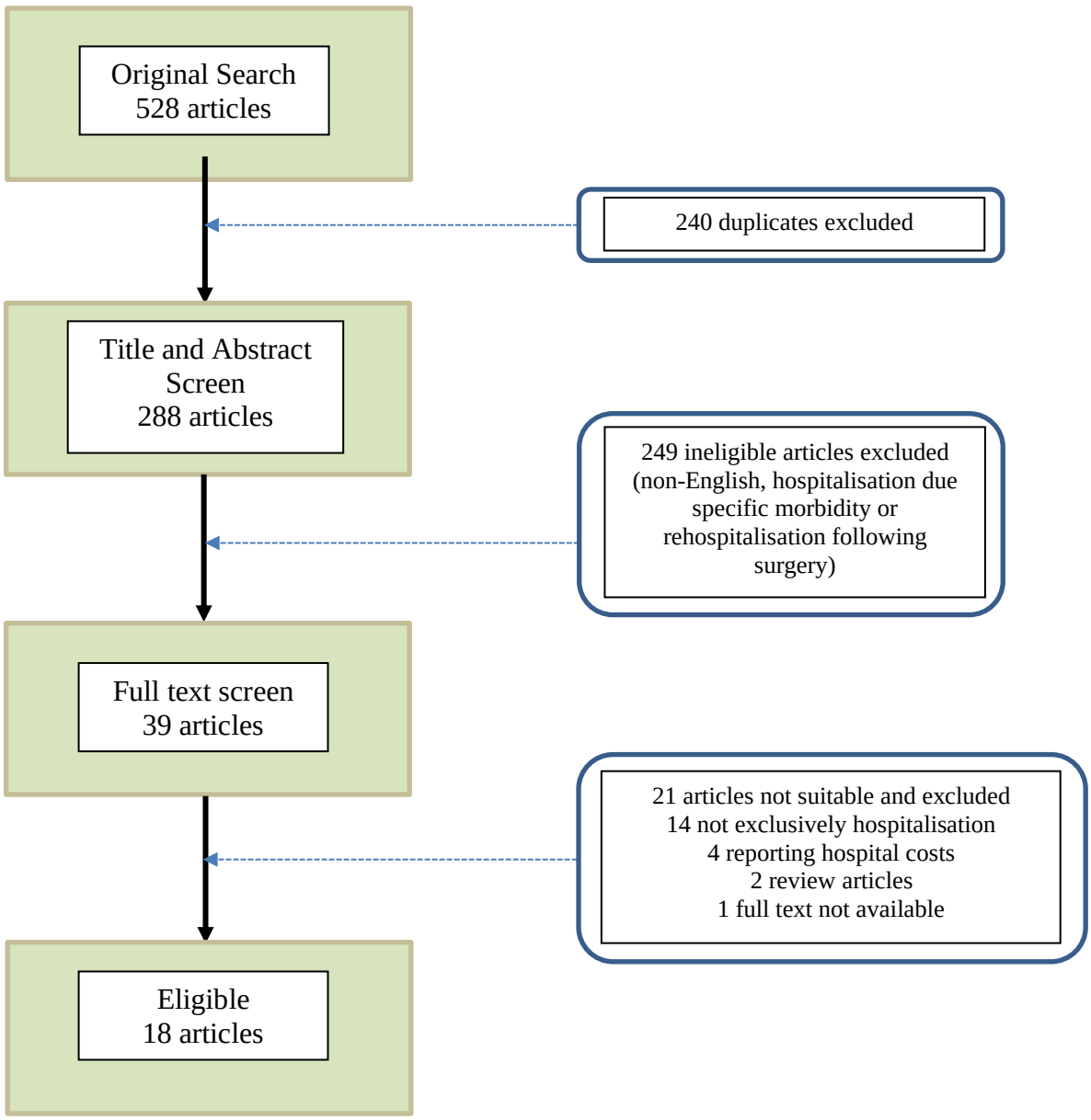


Figure 2-1 Process of article eligibility
PRISMA flow diagram showing the flow of information through the different phases of the literature review.

A total of 18 studies were included in the final review of relevant literature.

2.3.2 Summary

Most of the articles studied Northern American populations (n=13, 72.2%), the remainder of the studies were from Asia (n=3, 16.7%) and Europe (n=2, 11.1%) using a variety of sources to identify a target patient cohort including national CHD databases, national hospitalisation discharge diagnosis databases as well as local hospital medical records.

Most studies identified CHD lesions by using ICD and OPCS codes. Two versions of ICD revisions 9 and 10 were used. Little variability was encountered in the classification of included CHD lesions except Well et al.[70] who excluded isolated ASDs (due to the ambiguity of presence of PFO and/or ASD from clinical coding) and Simeone et al.[71] who excluded patients born pre-term with isolated diagnoses of ASD or PDA. Six of the studies focused on specific subset diagnoses of CHD including Fontan, ToF, septal defects and complex lesions.

Four studies [44,61,62,69] reported on the complexity of CHD lesions using the Bethesda classification of congenital conditions.[23] Bethesda classification separates CHD lesions into mild, moderate and great complexity as described in Section 1.8.3. However, two of the studies [44,69] used mild and complex to stratify severity of underlying lesion using Bethesda as a basis, where moderate and great complexity lesions were grouped together as 'complex' lesions. The remaining 2 studies used Bethesda in its classical sense.

Eleven articles studied hospitalisations only of adult patients, defined in their cohorts as aged ≥18 years old, except one which included all those aged >14 years old. Five studies included hospitalisation of all ages, whereas only one identified a cohort of adolescent and young adults aged 10 – 29.

A summary of the included articles is found in Table 2-1. grouped together by region of study.

Table 2-1 Summary table of literature review article baseline characteristics and CHD population cohort

North American studies

Study	Years of study	Ages	Mean age	Hospitalisations	No. Women (%)	Study location	Study design	Source of data	Lesions
Egbe et al.[72]	1990-2015	≥18	31	853	176 (48)	Mayo Clinic, USA	Single centre, retrospective cohort	Medical records	Fontan only
Cedars et al.[73]	1996 - 2014	≥18	33	1 001	199 (44)	St. Louis, USA	Single centre, retrospective cohort	Local database and medical records	Complex Lesions only
Opotowsky et al.[44]	1998 - 2005	≥18	53.1	168 073	89 079 (53)	USA	National, retrospective cohort	Nationwide Inpatient Sample Database	All
Schmidt et al.[66]	2000 - 2011	≥18	31.9	20 545	10 683 (52)	USA	National, retrospective cohort	Nationwide Inpatient Sample Database	ToF only
Tabtabai et al.[67]	2000-2011	>14	29.1	11 068	5 313(48)	USA	National, retrospective, cohort	Nationwide Inpatient Sample Database	Single Ventricle only
Islam et al.[62]	2003-2012	All	NR	103 034	47 887 (47)	Canada	National, retrospective cohort	Canadian Discharge Abstract Database	All
Agarwal et al.[69]	2003-2012	≥18	53.5	195 306	NR	USA	National, retrospective cohort	Nationwide Inpatient Sample Database	All
Mackie et al.[61]	2004-2014	All	54 (adults)	59 917	26 538 (44)	Canada	Regional, retrospective cohort	Canadian Discharge Abstract Database	All
Collins II et al.[74]	2004-2011	≥18	24.8	1 333	596 (45)	USA	Regional, retrospective cohort	Paediatric Health Information System	Fontan
Lu et al.[75]	2005-2009	10 to 29	NR	7 419	3264 (44)	California	Regional, retrospective cohort	Californian State Inpatient database	All
Simeone et al.[71]	2006-2011	All	NR	9 071	4559 (50)	Arkansas, USA	Regional, retrospective cohort	Arkansas State Inpatient Database	All (preterm ASD and PDA excluded)
Rodriguez III et al.[65]	2007	≥18	58	84 308	23 356 (55)	USA	National, retrospective cohort	Nationwide Inpatient Sample Database	Septal defects only
Well et al.[70]	2009-2018	≥18	NR	10 515	5 600 (54)	Texas, USA	Regional, retrospective cohort	Texas Inpatient Discharge Public Use File	Excludes isolated ASDs

European studies

Study	Year(s) of Study	Ages	Mean age	Hospitalisations	No. Women (%)	Study location	Study design	Source of data	Lesions
Billet et al.[76]	1994-2004	All	NR	NR	NR	England, UK	National, retrospective, cohort	Hospital Episode statistics	All
Verheugt et al.[42]	2001-2006	≥18	39	2 908	1569 (54)	Netherlands	National registry	CONCOR Dutch Registry	All

Asian studies

Study	Year(s) of Study	Ages	Mean age	Hospitalisations	No. Women (%)	Study location	Study design	Source of data	Lesions
Negishi et al.[77]	2005 - 2009	≥18	27	959	432 (45)	Japan	Single centre, retrospective cohort	Medical records	All
Koh et al.[78]	2007	≥18	37.6	108	38 (56)	Singapore	Single centre, retrospective cohort	Local database and medical records	All
Cui et al.[79]	2007-2011	All	NR	53 064	NR	Beijing, China	Single centre, retrospective cohort	Hospital Discharge Information System	All

The total numbers of hospitalisation observed in each study ranged from 108 – 195 306 with the studies spanning the years 1994 to 2018. One study[78] analysed only a single year only and was therefore unable to comment on temporal variation and 2 studies[71,77] reported only total hospitalisation with no data on temporal changes.

2.3.3 Lesions

Ten articles reported hospitalisation data on all CHD lesions regions including North America, Europe, England and Asia. Although not all studies reported rates of change in hospitalisation, they did include overall changes in the total number of hospitalisations and were therefore included. Several studies had lesion subsets within their cohort population and 6 studies had lesion specific populations. A summary table of main findings regarding change in hospitalisations and hospitalisation rates for specific lesions is found in Table 2-2.

Table 2-2 Summary table of the temporal changes in CHD lesions and lesion subset hospitalisations

Lesion	Study	Years of Study	Main findings
All CHD	Islam et al.	2003-2012	Annual hospitalisation rate +1.1%, p>0.001
	Mackie et al.	2001-2014	Hospitalisations +17.5%
	Agarwal et al.	2003-2012	Hospitalisations + 81.5%, p<0.001
	Lu et al.	2005-2009	Stable rates of Hospitalisations, no further detail
	Verheugt et al.	2001-2006	"admissions increased significantly each year", p<0.001
	Billet et al.	1994-2004	Hospitalisations +9.7%; Hospitalisation rate +16%
	Opotowsky et al.	1998 - 2005	Hospitalisations +101%
	Well et al.	2009-2018	Hospitalisations +41.4%, p<0.001
	Cui et al.	2007-2011	Hospitalisation rate +21.6% increase (10.2 to 12.4 per 100 000 persons)
ToF	Schmidt et al.	2000 - 2011	Hospitalisations +14.6%
Fontan	Tabtabai et al.	2000-2011	"Non statistical increase in Fontan hospitalisations"
	Collins II et al.	2004-2011	40% increase in Fontan hospitalisations

Seven studies reported on findings of overall hospitalisation. One study[75] concluded that there were "stable rates of hospitalisation" in patients aged 10 - 29, however no supporting further data were supplied. The remaining six studies reported increases in hospitalisation, ranging between 9.7%[76] to 101%.[44] Verheugt et al.[42] concluded "admissions increased significantly each year

($p<0.001$)," but did not give any further detail. Three studies reported on findings of hospitalisation rates. Islam et al.[62] reported an increase in annual hospitalisation rate of 1.1% and Cui et al.[79] reported an increase of 21.6% (12.2 – 12.4 per 100 000 persons). Billet et al.[76] observed an increase in the age standardised hospitalisation rate of all CHD lesions by 16% from 1995/96 to 2003/04.

A summary table of the findings in those articles that reported overall proportions of specific lesion hospitalisations compared with the total number of hospitalisations is shown in Table 2-3.

Table 2-3 Summary table of proportion of specific lesions hospitalisations compared to the overall hospitalisations observed.

Lesion	Study	Years of Study	Main findings
ASD	Verheugt et al.	2001-2006	18% of CHD hospitalisations
	Koh et al.	2007	24% of CHD hospitalisations
	Negishi et al.	2005 - 2009	39% of CHD hospitalisations
	Rodrigues et al.	2007	48% of CHD hospitalisations
VSD	Verheugt et al.	2001-2006	18% of CHD hospitalisations
	Koh et al.	2007	19% of CHD hospitalisations
	Negishi et al.	2005 - 2009	4% of CHD hospitalisations
	Rodrigues et al.	2007	7% of CHD hospitalisations
PDA	Verheugt et al.	2001-2006	1% of CHD hospitalisations
ToF	Verheugt et al.	2001-2006	11% of CHD hospitalisations
	Koh et al.	2007	13% of CHD hospitalisations
	Negishi et al.	2005 - 2009	11% of CHD hospitalisations
Coarctation	Verheugt et al.	2001-2006	10% hospitalisations
TGA	Verheugt et al.	2001-2006	5% hospitalisations
	Negishi et al.	2005 - 2009	5% of CHD hospitalisations
Ebstein's	Verheugt et al.	2001-2006	5% hospitalisations
AVSD	Verheugt et al.	2001-2006	2% of CHD hospitalisations
	Rodrigues et al.	2007	0.4% of CHD hospitalisations
Fontan	Negishi et al.	2005 - 2009	10% of CHD hospitalisations
	Egbe et al.	1990-2015	1% of CHD hospitalisations

The proportion of hospitalisations attributable to specific lesions was reported in several studies. The range of proportions for each lesion and number of studies reporting these ranges is given below:

- **ASD** – 4 studies. Range of 18 and 48% of all CHD hospitalisations
- **VSD -** 4 studies. Range of 4 and 19% of all CHD hospitalisations
- **PDA -** 1 study. 1% of all CHD hospitalisations
- **ToF -** 4 studies. Range of 11 and 13% of all CHD hospitalisations. Schmidt et al.[66] reported an increase in hospitalisation of patients with ToF of +14.6% between 2000 and 2011.
- **Coarctation of Aorta** – 1 study. 10% of all CHD hospitalisations

- **TGA** – 2 studies. Both reporting 5% of all CHD hospitalisations

- **Ebstein's anomaly** – 1 study. 5% of all CHD hospitalisations

- **AVSD** – 2 studies. Range 0.4 – 2% of all CHD hospitalisations.

- **Fontan.** 4 studies. 2 reporting proportions ranging between 1 and 10% of all CHD hospitalisations. Tabtabai et al.[67] observed no change in the overall number of hospitalisations during their study period, whereas Collins II et al.[74] found an increase of 40% in Fontan hospitalisations.

2.3.4 Lesion Complexity

2.3.4.1 Classical Bethesda Definition

Two studies used Bethesda classification to group CHD lesions together in a hierarchy of complexity (mild, moderate and great complexity).

Islam et al.[62] did not report the total number of hospitalisations in each complexity group in their study period 2003 to 2012. However, they observed that simple lesions had the largest number of hospitalisations, with simple lesion hospitalisations increasing by 2.8%, with the hospitalisation rate increasing from 21 to 24 per 100 000 over the study period. Moderate lesions were the second largest by hospitalisation, increasing by 1.3% over the study period. The moderate lesion hospitalisation rate increased from 13 to 14 per 100 000 of the general population over the study period. Great complexity lesions were the smallest of the 3 groups, and overall great complexity lesions hospitalisation increased by 3.2%. The great complexity lesion hospitalisation rate increased from 4 to 5 per 100 000 of the population over the study period. This study demonstrated that across all complexity lesion groups both the total hospitalisation and hospitalisation rate increased across the ranges of lesion complexity.

Mackie et al.[61] did not comment on temporal changes seen within each lesion severity grouping. However, they did observe that 75% of the total number of hospitalisations had mild, 21% had moderate and 4% had great complexity lesions.

2.3.4.2 Alternative Bethesda Definition

Two studies grouped lesions together using Bethesda classification as a basis for separating lesions but simplified it somewhat to include moderate and great complexity lesions together in a 'complex' group and renamed mild lesion group as 'simple'.

Agarwal et al.[69] found that hospitalisation rates for simple lesions increased by 101% ($p<0.001$) and a corresponding increase in the hospitalisation rate of patients with complex lesions of 53% ($p<0.001$) over the years 2003 to 2012.

Opotowsky et al.[44] found that annual hospitalisations for simple and complex lesions between the years 1998 and 2005 increased by 130% and 60% respectively. Simple defects increased as a proportion of ACHD hospitalisations from 54% to 61.5%, whereas complex lesions decreased from 34.8% to 27.5%

2.3.5 Sex

Fifteen articles reported on the baseline sex characteristics of their study cohort and provided hospitalisation rates based on sex. The distribution of women and girls in each study, as well as the percentage of total hospitalisations (if known) is shown in Table 2-1.

Those articles that studied all CHD hospitalisations, in both adults and in all ages, favoured no clear trend towards increased hospitalisation towards either sex. Four studies found that women had more frequent hospitalisations.[42,44,70,78] Five studies reported the opposite finding; hospitalisations in men with CHD were more frequent than women. Although Billet et al.[76] did not make available the overall hospitalisation or percentage, they found that the hospitalisation rate in men and boys increased from 30.7 to 35.5 per 100 000 and from 28.2 to 32.8 per 100 000 in women and girls over a 10-year period (1994 – 2004) and hospitalisation rates higher in men and boys in each year of their study. Simeone et al.[71] found no difference in hospitalisations with regards to sex.

Four studied hospitalisations in a cohort of patients with great complexity (single ventricle, Fontan and composite of great complexity lesions) all found that women had less hospitalisations compared to men (range 44 – 48%). Whereas,

Rodriguez et al.[65] investigated hospitalisation of septal defects. These lesions would classify as either mild (ASD and VSD) or moderate (AVSD) complexity and the study reported that women had higher rates of hospitalisation (55%) compared to men. Schmidt et al.[66] found that women with ToF had higher proportion of hospitalisation (55%) than men, although the female share of hospitalisations fell from 55% in 2009 to 48% in 2018. Cedars et al.[73] found that 48% of all ToF hospitalisations were in women.

2.3.6 Age

Twelve of the 18 studies had baseline characteristics that included the mean age of their study cohort. The mean hospitalisation age for each study (where available) is summarised in Table 2-1.

Three of the articles that studied adult (ages ≥18) hospitalisations for all CHD lesions found that the mean age at hospitalisation was >50 (range 53.1-54). Mackie et al.[61] found an increase in the mean age at hospitalisations from 54 to 55 in the period 2004-2013. Agarwal et al.[69] found only a small increase in the mean age from 53.5 to 57.5 over the period 2003-2012. Opotowsky et al.[44] found that the mean age at hospitalisation for simple defects increased from 53.5 to 55.9 ($p<0.001$) but found no change in the mean age at hospitalisation of complex defects. Verheugt et al.[42] found the overall mean age to be 39 which is slightly lower than the other studies. The mean age of hospitalisation in those patients with ASD, Bicuspid aortic valve, Ebstein's and PDA ranged from 40 – 45.

The oldest mean age at hospitalisation was observed by Rodrigues et al.[65] although their study population was a shunt subset of CHD lesions. They found a mean hospitalisations age of 58, with an increase of 65% in the total number of hospitalisations of those aged >50. The youngest mean hospitalisation age (24.8) in a lesion group was reported by Collins et al.[74] in their study population subset of patients with Fontan physiology. They did however observe an increase in the mean age from 23 to 25 over their study period.

Four studies investigated all hospitalisations of all ages. Although Islam et al.[62] did not publish a mean age for young and old, they found that infants (<1-year-old) made up 39% of all hospitalisations and those aged >65 comprised 16.3% of

the total number of hospitalisations. The hospitalisation rate increased by 4% per year in adults and by 6.5% per year for those aged >65. There was no overall change observed in infants, although this age group had consistently the highest hospitalisation rate per 100 000 of the population throughout the study. Billet et al.[76] also found that around 33% of all hospitalisations were in infants, and that the rate of hospitalisation among this infant population were stable, although among all other age groups the hospitalisation rate rose. Cui et al.[79] found that 50% of hospitalisations had occurred in children younger than 5, with adults over the age of 30 making up 30% of all hospitalisations.

Schmidt and Cedars et al.[66,73] both had ToF as specific lesions of interest in their study. They found a mean age at hospitalisation of 31.9 and 37 respectively in their cohort of adult patients with ToF. Schmidt et al.[66] found an increase in the mean age at hospitalisation from 30.6 to 32.5 for ToF over their study period.

2.4 Discussion

Peer-reviewed, published research on hospitalisation data and temporal trends in hospitalisation rates for patients with CHD is sparse. Eighteen articles were returned in the search of Ovid and Medline that met my systematic search criteria. This is in most part due to several studies including not only hospital discharges but emergency department attendances, outpatient clinic utilisation and a composite of all the above. Readmissions following intervention or surgical procedure as well as specific co-morbidity-driven hospitalisation (such as heart failure or arrhythmia) are other reasons why many articles were ineligible. Whilst I appreciate that heart failure, arrhythmia and endocarditis are some of the main reasons for admission to hospital for many patients with CHD, the aim of this literature review was to find relevant articles on all CHD hospitalisations. The eighteen articles that were included covered all hospitalisations of patients with CHD including cardiac (including the common CHD associated comorbidities of heart failure, arrhythmia and endocarditis) and non-cardiac complications and therefore those cardiac complications noted above will have been robustly included within these publications, but not explicitly detailed. Specific studies on CHD related comorbidity and hospitalisation may be of relevant to future studies but will not be discussed further in this thesis.

Although there are limited publications available, there was articles from all continents reporting data on CHD hospitalisations. There appears to be a bias towards publication of studies with a North American population. The sampling method used in the USA uses the NIS, which is a nationwide sample of a predetermined number of hospitals (approx. 20% across the country). Discharge diagnoses and hospitalisations in these pre-determined hospitals are then weighted to create an estimation for the hospitalisation for the USA. Whilst this is an estimate of the overall hospitalisation use, it is not an accurate individual count of hospitalisation. The insurance-based healthcare system design in the USA also makes it difficult to translate hospitalisations data in the USA to that of a free at point-of-access national healthcare system for patients who reside in any part of the UK.

Different means of identifying a CHD patient cohort to analyse have been used by the authors including single centre medical records, regional and national hospitalisation discharge databases as well as national CHD registries. Although a single centre, medical records-based method of examining CHD hospitalisations could be used in Scotland, we are fortunate to have access to nationwide linked database (SMR) of coded discharge diagnoses which can also be utilised.

ICD and OPCS appears to be a recognised means of identifying patients with CHD from the general population within hospital discharge coding. Although there is disparity between some of the published articles on classification of severity of underlying CHD lesion, the Bethesda classification of mild, moderate and great complexity appears to be used as often as other alternative methods. Although, using simple and complex seems a more straightforward means of dividing diagnoses with regards to lesion severity, the rationale behind the derivation of the Bethesda classification would be lost. One can already appreciate the heterogeneity and difficulty in making comparisons between all comers for CHD from the relatively small number of studies that is presented as part of this literature review.

The overall number of patients requiring hospitalisation with an underlying diagnosis of CHD is increasing, and in some cases with overall hospitalisations numbers increasing by over 100% between 1998 – 2005.[44] Even when hospitalisations are standardised to the total population numbers the

hospitalisation rates have also shown to be increasing up to 1.1% per year and 21% over the total timeline (2007 – 2011) of some studies.[62,79] Only one study concluded that there were stable hospitalisation rates throughout its period of study, although that was limited to patients aged 10 – 29. With almost universal consensus in the reporting of increasing hospitalisation and hospitalisation rates it reflects an increasing prevalence of patients with underlying CHD in the population. This is likely a composite of factors including increased use and quality of diagnostic infrastructure including echocardiography, CT and CMR meaning that some lesions of mild severity that would have previously gone undiagnosed, are now being reported, as well as the increased survival of patients with CHD.

The difference in hospitalisations with regards to sex is interesting. When overall hospitalisations are taken into consideration there is no clear indication that either sex has a more frequent hospitalisation or increased hospitalisation rates among the published data. In fact, one such study[76] which studies a population most similar to that in Scotland found that although the hospitalisations rate is increasing in both sexes, the rate of hospitalisations among men and boys were higher in every year of their study when compared to women and females. Those studies that examined specific lesions found sex difference in the burden of hospitalisations. Women were more likely than men to have hospitalisations with shunt lesions, as well as in lesions of mild severity. Those studies that had complex lesions and Fontan physiology found that women had less hospitalisations than men, and those articles that studies ToF and lesions of moderate severity did not have an overall difference between the 2 sexes. This reflects what is already understood about some CHD lesions occurring more in women and girls than in men and boys. ASDs, VSDs and those lesions mild severity have a greater live birth incidence in women. Lesions of greater complexity including TGA, ToF, aortic lesions and those lesions requiring palliative repairs forming Fontan physiology have a lower birth incidence in women.[80] These baseline sex differences in birth incidence imply that there is varying background prevalence of lesions in both sexes. With differing lesion prevalence in either sex, the likelihood of having a hospitalisation with that lesion being recorded as a primary or secondary diagnosis will likely follow a similar trend and offers one such explanation for the difference seen. Obstetric

hospitalisations will also likely play a role here. Those mothers with simple CHD lesions on the most part having relatively normal pregnancies and peripartum period, whereas those women with lesions of great complexity in some cases being counselled against pregnancy, with the resulting decrease in obstetric hospitalisations for women with great lesions of great complexity.

The mean age of hospitalisations in those studies that included patients of all ages or adults shows some variation, However, 3 large patient cohort studies demonstrated a mean age >50 and these 3 studies demonstrated an increasing mean age of hospitalisation throughout their study period. One such study demonstrated that there was an increase of 65% in the hospitalisation in those aged over 50. The highest hospitalisations rates were seen among infants. Those studies that included only those lesions of moderate or great complexity demonstrated a younger age at hospitalisation, although within their study period the mean age was increasing with time. These findings are likely to reflect the natural history of CHD lesions. Those lesions of mild severity in many cases do not cause haemodynamic sequalae until later in life and therefore may not present as new diagnoses until later in life when there is evidence of decompensation or have been followed up over many years as outpatients not requiring hospitalisation. However, those lesions of moderate and great complexity usually have such significant haemodynamic upset that they require operative intervention at a much younger age, and in some cases in infancy. Most of these repairs are palliative, and in most cases will require future intervention. Those patients with moderate and great complexity are more likely to have associated cardiac co-morbidities such as arrhythmia, valvular dysfunction and heart failure and in many cases will require hospitalisations as a result.

What is clear is that the mean age at hospitalisation is increasing among all lesions and lesion severity groups. This is a demonstration of what is understood about CHD care and survival and is included in most introductory paragraphs in any contemporary pieces of research or editorial on CHD – is that survival of patients with CHD is increasing. Estimates suggest 90% of individuals born with CHD now reach adulthood.[81] Patients may now present either as late complications of prior operative repairs or requiring hospitalisation not only for

sequalae of underlying congenital cardiac related conditions but due to acquired conditions including pregnancy, coronary artery disease due to smoking, trauma due to activity in sports and other age-related complaints.

These studies reporting age at hospitalisation indicate that not only are patients surviving to adulthood but are thriving well into adult life and this is testament to the improvements in care that is now available to all patients born with CHD who require hospitalisation not only for sequalae of underlying congenital cardiac related conditions but also due to acquired conditions including pregnancy, coronary artery disease due to smoking and other age-related complaints.

Although articles with respect to SED and CHD were present in the published literature and were found as part of the literature search, I was unable to include them in this literature review as the articles themselves referred to healthcare utilisation including all aspects of health care and not only hospitalisation.

2.5 Conclusion

Although there are limited publications reporting CHD hospitalisation, the use of ICD and OPCS to identify CHD hospitalisation from national hospital discharge databases from the general population has precedent. The use of the Bethesda classification for stratification of mild, moderate and great complexity is used to group lesions of similar severity together, although how this is applied appears to differ. CHD hospitalisations and hospitalisation rate are on the increase. There appears to be no overall difference in hospitalisation due to sex, although the rates for individual lesions and lesion severity appears to differ between men and women. The age at hospitalisation for all comers with CHD is increasing, although the highest hospitalisation rates are seen among infants. I will explore these areas in more detail in my thesis and try and determine these trends in the Scottish population as well as examining the association between SED and CHD hospitalisation rates.

3 Aims and Objectives.

3.1 Aims

This thesis aims to describe index hospitalisation among individuals with CHD in Scotland between the years 1990 – 2015.

3.2 Objectives

Using the aim outlined in Section 3.1, the following objectives were formulated:

1. To describe the baseline characteristics of patients with an index hospitalisation of CHD in Scotland between 1990 - 2015

2. To examine the temporal changes in index hospitalisation of CHD lesions and of CHD lesion severity within this cohort

3. To describe temporal variations in index hospitalisation of patients with CHD with respect to underlying patient characteristics including sex, age and SED

4 Methods

4.1 Introduction

This Chapter outlines the methodology used to complete this thesis. All aspects will be common to each subsequent chapter. Where a more specialised or detailed technique was used it will be outlined in more detail in the relevant Chapter.

4.2 Data request

4.2.1 Privacy Panel Application

Access to any of the nationally gathered health records (for example the SMR) or patient data that is not necessary for direct clinical patient care requires prior authorisation from the PBPP in Scotland. As such, application to the PBPP was undertaken and granted prior to submission request for data extraction to ISD via the electronic Data Research and Innovation Service (eDRIS).

The application to the PBPP was submitted for data extraction for the reasons of audit, research and service improvement. Non-identifiable information would be gathered from several national linked patient databases to cover all the Health Boards within Scotland.

Due to the small numbers of individuals in the requested data, an application amendment was necessary to ensure that all extracted information was non-identifiable and that the information regarding vulnerable patient cohorts would remain anonymous. The original request was for date-specific information including birth, admission and death. This was refused, and as such the request was amended to include the individual age at each episode, including age at birth and death.

4.2.2 Inclusion

Identification of patients with CHD was achieved by using both diagnostic (ICD) and procedural (OPCS) descriptors that were specific to CHD.

Patients are labelled with a diagnosis of CHD if they have a principal or secondary diagnostic pre-determined ICD classification 9 or 10 descriptors

identifying a congenital heart disease lesion and whom had hospitalisation in Scotland within the years 1990 – 2015 (inclusive) within SMR01 records.

The ICD codes used to identify patients with a diagnosis of CHD included,

- ICD-9: 745 – 747
- ICD-10: Q20 – 28.

The ICD-10 codes have been described in detail in Table 1-1. Each lesion and corresponding ICD code, as well as descriptor, will be detailed in Chapter 4.2.3.

OPCS codes from chapters L (heart) and K (arteries and veins) were used to identify CHD-specific codes. These procedural codes will be described in detail with respect to each lesion in Chapter 4.2.3.

As well as diagnosis and procedural codes demographic information for each patient was recorded including:

- Age at hospitalisation
- Year of hospitalisation
- Sex
- SIMD quintiles

4.2.3 CHD Diagnostic Groupings

The heterogeneity of CHD can be a hurdle in any research into CHD. It is also why randomised controlled trials in CHD populations have proven difficult. Even within clinical practice and access to clinical notes, diagnosis of underlying congenital diagnosis nomenclature can be challenging. Consequently, enabling accurate diagnosis and grouping of patients with CHD from coded clinical records without access to clinical notes or registry data can prove to be difficult. By combining both procedural and diagnostic codes to describe repairs more accurately, a more complete picture of the current and previous cardiac

anatomy can be obtained. I have used 12 groupings of CHD lesions, based on lesion type and physiology, with similarity to other lesions groupings used in the literature. Those groups are:

1. Aortic anomalies
2. Atrial septal defects
3. Atrioventricular septal defects
4. Ventricular septal defects
5. Tetralogy of Fallot
6. Complex lesions
7. Ebstein's anomaly
8. Fontan physiology
9. Patent ductus arteriosus
10. Systemic right ventricle
11. Transposition of the great arteries with arterial switch
12. Congenital valvular lesions
13. Other lesions

4.2.3.1 Aortic Anomalies

ICD and OPCS codes in this group relate to malformation of the usual development of the aorta. Coarctation of the aorta is by far the most common congenital lesion to affect the aorta, but a range of other malformations can occur.[82]

The diagnostic codes and descriptors of these lesions are listed in Table 4-1.

Table 4-1 ICD codes describing aortic anomalies

ICD Version	ICD Code	Coding Descriptor
9	747.1	Coartcation of the Aorta
	747.10	Coarctation of aorta (preductal) (post-ductal) Hypoplasia of aortic arch
	747.11	Interruption of the aortic arch
	747.2	Other anomalies of aorta
	747.20	Anomaly of aorta, unspecified
	747.21	Anomalies of aortic arch Anomalous origin, right subclavian artery Dextraposition of aorta Double aortic arch Kommerell's diverticulum Over-riding aorta Persistent: - Convolutions, aortic arch - Vascular ring EXCLUDES Hypoplasia of aortic arch (747.10)
	747.22	Atresia and stenosis of aorta Absence of aorta Aplasia of aorta Hypoplasia of aorta Stricture of aorta Supra (valvular) – aortic stenosis EXCLUDES: Congenital aortic (valvular) stenosis or stricture, (746.3) Hypoplasia of aorta in hypoplastic left heart syndrome (746.7)
	747.29	Other Aneurysm of sinus of Valsalva Congenital: Aneurysm of aorta
10	Q25.1	Coarctation of aorta (preductal) and (post ductal)
	Q25.2	Atresia of the Aorta
	Q25.3	Stenosis of aorta Supravalvular aortic stenosis

		EXCLUDES: Congenital aortic stenosis (Q23.0)
	Q25.4	Other congenital malformations of aorta Absence Aplasia Congenital: - Aneurysm - Dilatation Aneurysm of the Sinus of Valsalva (ruptured) Double aortic arch [vascular ring of aorta] Hypoplasia od aorta Persistent: - Convolutions of the aortic arch - Right aortic Arch EXCLUDES Hypoplasia of the aorta in HLH (Q23.4)

Operative codes associated with anomalies of the aorta are listed in Table 4-2.

Table 4-2 OPCS codes describing procedural repairs of aortic anomalies

OPCS Code	Descriptor
L23.1	Plastic repair of aorta and end-to-end anastomosis of aorta
L23.2	Plastic repair of aorta using subclavian flap
L23.4	Release of vascular ring of aorta
L23.7	Repair of interrupted aortic arch

4.2.3.2 Atrial Septal Defects

ICD and OPCS codes in this group describe malformations of the development of the inter-atrial septum. Due to the nature of the underlying code, I was unable to separate PFO from that of defects of the secundum atrial septum. Although PFO and ASD share a lesion within the same cardiac chamber, the presence of a PFO is not always thought to be a congenital cardiac lesion with pathological sequalae (only in conditions of paradoxical embolus leading to cryptogenic stroke), although the same could be said for an ASD with a non-significant left-to-right shunt and no evidence of dysrhythmia or paradoxical thrombotic event.

Partial anomalous pulmonary venous drainage (PAPVD), which is commonly associated with defects of the atrial septum, has also been included in the group along with ASD as physiologically they behave similarly to a left-to-right shunt at

atrial (pre-tricuspid) level. PAPVD is also thought to occur in 10-15% of ostium secundum ASD and up to 85% of patients with a sinus venosus ASD.[83,84]

The ICD diagnostic codes used to identify ASD are summarised in Table 4-3.

Table 4-3 ICD codes describing defects atrial septal defects

ICD Version	Code	Descriptor
9	745.5	Ostium Secundum type atrial septal defect Defect: - atrium secundum - Fossa ovalis - Lutembcher's syndrome - Patent or persistent foramen ovale (PFO) or ostium secundum
	747.42	PAPVD
10	Q21.1	Coronary sinus defect PFO Ostium secundum defect (type II) Sinus Venosus defect
	Q26.3	PAPVD

Operative and procedural codes associated with defects of the inter-atrial septum are shown in Table 4-4.

Table 4-4 OPCS codes describing procedural repairs of the atrial septum

OPCS Code	Descriptor
K10.1	Repair of defect of interatrial septum using prosthetic patch
K10.2	Repair of defect of interatrial septum using pericardial patch
K10.3	Primary repair of defect of interatrial septum
K10.4	Revision of repair of defect of interatrial septum
K10.5	Repair of defect of interatrial septum using prosthetic patch
K10.8	Other specified
K10.9	Unspecified
K13.3	Percutaneous transluminal repair of defect of interatrial septum using prosthesis
K13.4	Percutaneous transluminal repair of defect of interatrial septum NEC (not elsewhere classified)
K20.1	Correction of persistent sinus venosus

K20.2	Correction of partial anomalous pulmonary venous drainage

4.2.3.3 Atrioventricular Septal Defects

ICD and OPCS codes in this group describe malformations in the development in both the atrial and ventricular septum known as atrioventricular septal defects. These cardiac lesions are also known as endocardial cushion defects. The ICD descriptors in both the ICD versions 9 & 10 include both primum ASD and AVSD together. These are anatomically different but share common downstream cardiac complications, such as conduction abnormalities and defects of the atrioventricular valves. Their indistinguishability from ICD classification alone means that that they are included together in the same classification of AVSD.

The ICD diagnostic codes used to identify ASD are summarised in the Table 4-5.

Table 4-5 ICD codes describing atrioventricular septal defects

ICD Version	Code	Descriptor
9	745.6	Endocardial cushion defects
	745.60	Endocardial cushion defect, unspecified type
	745.61	Ostium primum defect Persistent ostium primum
	745.69	Other: Absence of atrial septum Atrioventricular canal type ventricular septal defect Common atrioventricular canal Common atrium
10	Q21.2	Atrioventricular septal defect: Common atrioventricular canal Endocardial cushion defect Ostium primum atrial septal defect (type I)

Operative and procedural codes associated with defects of the atrioventricular septum are shown in Table 4-6.

Table 4-6 OPCS codes describing procedural repairs of atrioventricular septal defects

OPCS Code	Descriptor
K09.1	Repair of defect of AVSD using dual prosthetic patches

K09.2	Repair of defect of AVSD using prosthetic patch NEC
K09.3	Repair of AVSD using tissue graft
K09.4	Repair of persistent ostium primum defect
K09.5	Primary repair of defect of AVSD NEC
K09.6	Revision of repair of defect of AVSD
K09.8	Repair of AVSD other specified
K09.9	Repair of AVSD otherwise unspecified

4.2.3.4 Ventricular Septal Defects

ICD and OPCS codes in this group describe malformations in the development of in the inter-ventricular septum. Acquired ventricular septal defects, usually as a result of myocardial infarction are not included. They have separate ICD coding and are therefore easily distinguished.

The ICD diagnostic codes used to identify VSD are found in the Table 4-7.

Table 4-7 ICD codes describing ventricular septal defects

ICD Version	Code	Descriptor
9	745.4	Ventricular Septal defect: Eisenmenger's defect or complex Gerbode defect Interventricular septal defect Left ventricular-right atrial communication Roger's disease EXCLUDES: Common atrioventricular canal type (745.69) Single ventricle (745.3)
10	Q21.0	Ventricular Septal Defect EXCLUDES Acquired cardiac septal defect I51.0

Operative and procedural codes associated with the repair and intervention to ventricular septal defects are shown in Table 4-8.

Table 4-8 OPCS codes describing procedural repairs of ventricular septal defects.

OPCS Code	Descriptor
K11.1	Repair of defect of interventricular septum using prosthetic patch

K11.2	Repair of defect of interventricular septum using pericardial patch
K11.3	Repair of defect of interventricular septum using tissue graft NEC
K11.4	Primary repair of defect of interventricular septum NEC
K11.5	Revision of repair of defect of interventricular septum
K11.6	Repair of multiple defects of interventricular septum
K11.7	Repair of interventricular septal defect using intraoperative transluminal prosthesis
K11.8	Repair of interventricular septal defect, other specified
K11.9	Repair of interventricular septal defect, otherwise unspecified
K13.1	Percutaneous transluminal repair of defect of interventricular septum using prosthesis
K13.2	Percutaneous transluminal repair of defect of interventricular septum NEC

4.2.3.5 Ebstein's Anomaly

ICD codes in this group describe a collection of malformations known as Ebstein's anomaly, characterised by malformation of the tricuspid valve and right ventricle secondary to:

- Failure of delamination of the septal and posterior leaflets of the tricuspid valve
- Apical displacement of the tricuspid valve annulus
- Dilatation of the 'atrialised' portion of the right ventricle
- Redundancy, tethering and fenestration of the anterior tricuspid valve leaflet
- Dilatation of the atrioventricular junction i.e.: the true tricuspid annulus[85]

Diagnostic coding to describe Ebstein's anomaly are shown in Table 4-9.

Table 4-9 ICD codes describing Ebstein's anomaly

ICD Version	Code	Descriptor
9	746.2	Ebstein's anomaly
10	Q22.5	Ebstein's anomaly

There are no specific operative or procedural codes for the intervention or repair of Ebstein's anomaly. There are procedural codes that describe intervention to the tricuspid valve, but they are not specific to Ebstein's or to CHD in general and these have not been included in the diagnostic criteria for identification of Ebstein's for the purpose of this thesis.

4.2.3.6 Patent Ductus Arteriosus

ICD and OPCS codes in this group describe the persistence of a foetal structure known as the ductus arteriosus after birth. This is a vascular structure which connects the main pulmonary artery to the aorta and allows blood to bypass the pulmonary circulation in utero. It usually closes spontaneously after birth, generally within the first 48 hours of life. Failure of this structure to close is referred to as a PDA. Diagnostic coding to describe PDA is shown in Table 4-10.

Table 4-10 ICD codes describing patent ductus arteriosus

ICD Version	Code	Descriptor
9	747.0	Patent ductus arteriosus Patent ductus Botalli
10	Q25.0	Patent Ductus Arteriosus Patent ductus Botallo

Operative codes relating to the intervention and repair of PDA are shown in Table 4-11.

Table 4-11 OPCS codes describing procedural repairs of patent ductus arteriosus

OPCS Code	Descriptor
L02.1	Division of PDA
L02.2	Ligature of PDA
L02.3	Closure of PDA NEC
L02.4	Revision of the correction of PDA
L02.8	Repair of PDA, other specified
L02.9	Repair of PDA, other unspecified

L03.1	Percutaneous occlusion of PDA

4.2.3.7 Systemic Right Ventricle (SRV)

ICD and OPCS codes in this group describe the cardiac malformations and operative procedures which describe anatomy whereby the systemic ventricle i.e. the ventricle that supplies arterial blood into the systemic circulation and not the pulmonary circulation, is the morphological right ventricle. The 2 groups cardiac lesions that SRV would describe include those patients with TGA who have underwent atrial inversion or switch (Mustard or Senning procedure) or those patients with unrepaired congenitally corrected transposition of great arteries.

To accurately describe someone with TGA and atrial switch, both the ICD and OPCS descriptor is required. If someone with ICD codes 745.10 or Q20.3 does not have an OPCS code that describes an atrial switch, then these patients will be included under Complex and not SRV.

The diagnostic ICD codes used to describe these lesions are shown in Table 4-12.

Table 4-12 ICD codes used to describe systemic right ventricle.

ICD Version	Code	Descriptor
9	745.10	Complete transposition of the great vessels Transposition of the great vessels: - NOS - Classical
	745.12	Corrected transposition of the great arteries (ccTGA)
10	Q20.3	Discordant ventriculo-arterial connection Dextrotransposition of aorta Transposition of great vessels (complete)
	Q20.5	Discordant atrioventricular connection Correct transposition Laevotransposition Ventricular inversion

Operative codes that would also describe patients with a systemic right ventricle include those codes under K05 which are used to describe procedures relating to atrial switch in TGA. The OPCS codes are shown in Table 4-13.

Table 4-13 OPCS codes describing procedures consistent with presence of a systemic right ventricle

OPCS Code	Descriptor
K05.1	Reconstruction of atrium using atrial patch repair for TGA
K05.2	Reconstruction of atrium using atrial wall for TGA
K05.8	Reconstruction of atrium in TGA, Other specified
K05.9	Reconstruction of atrium in TGA, Other unspecified

Also included are those procedures in OPCS version 3 codes 3153 and 323, but only if they are associated with an ICD code describing TGA.

4.2.3.8 Transposition of the Great Arteries with Arterial Switch

ICD and OPCS codes in this group describe those individuals who are born with TGA who proceed to an operative repair known as an arterial switch, as opposed to the atrial switch described above.

The congenital anatomy of TGA (or dTGA) is that of ventriculoarterial discordance with the aorta arising from the morphological right ventricle and the pulmonary artery arising from the morphological left ventricle. Those patients who undergo an arterial switch end up with both an anatomical and physiological repair of the underlying congenital defect, whereby the morphological left ventricle supplies the systemic arterial circulation, and the morphological right ventricle supplies the pulmonary circulation.

To accurately identify these individuals, I will require to have both the ICD description of TGA and the procedural code for arterial switch, otherwise they will be captured in the ‘complex’ grouping.

The diagnostic ICD codes used to describe these lesions are shown in Table 4-14.

Table 4-14 ICD codes describing transposition of the great arteries

ICD Version	Code	Descriptor
9	745.10	Complete transposition of the great vessels Transposition of the great vessels: - NOS - Classical
10	Q20.3	Discordant ventriculo-arterial connection Dextrotransposition of aorta Transposition of great vessels (complete)

Operational codes that describe arterial switch in combination with the ICD codes above in shown in Table 4-15.

Table 4-15 OPCS codes describing procedural repairs resulting in an arterial switch

OPCS Code	Descriptor
K06	Other repair of transposition of great arteries
K06.1	Repositioning of transposed great arteries – arterial switch
K06.8	Other, specified
K06.9	Other, unspecified

4.2.3.9 Fontan

Although patients with CHD palliated with procedures resulting in Fontan physiology form a well-defined group of patients in the real world, they are not described by any ICD code. A combination of an underlying anatomical lesion, as described by the ICD code combined with that of an OPCS procedural code describing the formation of Fontan circulation would be required to accurately describe underlying cardiac anatomy and their post-operative Fontan formation. One exception to this rule are those patients who have a diagnosis of hypoplastic left heart syndrome who have survived to adulthood, who have such a severe underlying anatomy and physiology that one presumes that they have been palliated with staged procedures resulting in a Fontan physiology to allow them to have survived.

With this in mind, I have grouped those patients with a known Fontan by an ICD diagnosis of HLH or any of the OPCS codes listed below. Other lesions such as tricuspid atresia (Q22.4), which can often be repaired with Fontan will only be included if the OPCS coding is listed.

The diagnostic ICD codes used to describe lesions are shown in Table 4-16.

Table 4-16 ICD lesions describing lesions consistent with Fontan physiology

ICD Version	Code	Descriptor
9	746.7	Hypoplastic left heart syndrome
10	Q23.4	Hypoplastic left heart syndrome

Operational codes that describe Fontan creation are shown in Table 4-17.

Table 4-17 OPCS codes describing operative procedures resulting in formation of a Fontan

OPCS Code	Descriptor
K17	Repair of univentricular heart (specified)
K17.1	TCPC with extra-cardiac inferior caval vein to pulmonary artery conduit
K17.2	TCPC with lateral atrial tunnel
K17.7	Conversion of atrial pulmonary anastomosis to total pulmonary connection
K18.2	Creation of valved conduit between right atrium and pulmonary artery
K19.2	Creation of conduit between right atrium and pulmonary artery
L09.1	Creation of anastomosis to pulmonary artery from vena cava

4.2.3.10 Congenital Valvular Defects

ICD codes in this group describe congenital malformation of the 4 cardiac valves. They do not include acquired valvular defects such as ‘senile’ aortic stenosis, which is an acquired defect and have distinguishable ICD codes.

The ICD codes to describe congenital valvular conditions are shown in Table 4-18.

Table 4-18 ICD codes describing congenital valvular defects

ICD Version	Code	Descriptor
9	746.3	Congenital stenosis of the aortic valve EXCLUDES: Congenital subaortic stenosis (746.81) Supravalvular aortic stenosis (747.22)
	746.4	Congenital insufficiency of aortic valve Bicuspid aortic valve

		Congenital aortic insufficiency
	746.81	Subaortic Stenosis
	746.5	Congenital mitral stenosis Fused commissure of mitral valve Parachute deformity of mitral valve Supernumerary cusps of the mitral valve
10	Q23.0	Congenital aortic: - Atresia - Stenosis EXCLUDES Congenital subaortic stenosis Q24.4 Mitral stenosis associated with HLH (Q23.4)
	Q23.1	Congenital insufficiency of aortic valve Congenital aortic incompetence Bicuspid aortic valve
	Q24.4	Congenital subaortic stenosis
	Q23.8	Other congenital malformation of aortic and mitral valves
	Q23.9	Congenital malformations of aortic and mitral valves, unspecified
9	746.5	Congenital mitral stenosis Fused commissure of mitral valve Parachute deformity of mitral valve Supernumerary cusps of the mitral valve
	746.6	Congenital mitral insufficiency
10	Q23.2	Congenital mitral stenosis Congenital mitral atresia
	Q23.2	Congenital mitral insufficiency
9	746.0	Anomalies of the pulmonary valve EXCLUDES - Infundibular or subvalvular pulmonic valve stenosis (746.83) - ToF (745.2)
	746.00	Pulmonary valve anomaly, unspecified
	746.02	Congenital pulmonary valve stenosis
	746.83	Infundibular pulmonic stenosis
	746.09	Other Congenital insufficiency of the pulmonary valve Fallot's triad or trilogy
10	Q22.1	Congenital pulmonary valve stenosis
	Q22.2	Congenital pulmonary valve insufficiency
	Q22.3	Other congenital malformations of pulmonary valve, NOS
	Q24.3	Pulmonary infundibular stenosis
	Q22.8	Other congenital malformations of the tricuspid valve
	Q22.9	Congenital malformation of tricuspid valve, unspecified

There are no specific operative or procedural codes that describe only the repair and/or replacement of congenital valvular lesions. Therefore, no procedural or operative coding has been used to identify those patients with congenital valvular lesions.

4.2.3.11 Tetralogy of Fallot

ICD and OPCS codes in this group describe groups of individuals who are born with 4 cardiac lesions that are known as Tetralogy of Fallot (ToF). The cardiac lesions are:

1. Pulmonary stenosis
2. Ventricular Septal defect
3. Right ventricular hypertrophy
4. Overriding aorta

The diagnostic codes describing ToF are shown in Table 4-19.

Table 4-19 ICD codes describing Tetralogy of Fallot

ICD Version	Code	Descriptor
9	745.2	Tetralogy of Fallot EXCLUDES: Fallot's Triad (746.09)
10	Q21.3	Tetralogy of Fallot

Operative codes relating to the intervention and repair of ToF are shown in Table 4-20.

Table 4-20 OPCS codes describing procedural repairs of Tetralogy of Fallot

OPCS Code	Descriptor
K04	Repair of ToF (including Fallot type pulmonary atresia with VSD)
K04.1	Repair of ToF using valved right ventricular outflow conduit
K04.2	Repair of ToF using right ventricular outflow conduit NEC
K04.3	Repair of ToF using transannular patch

K04.4	Revision of repair of ToF
K04.5	Repair of ToF with absent pulmonary valve
K04.6	Repair of Fallot-type pulmonary atresia with aortopulmonary collaterals
K04.8	Other, specified
K04.9	Other, unspecified
K08.2	Repair of Fallot-type double outlet right ventricle

4.2.3.12 Complex Lesions

ICD and OPCS codes in this group describe collections of diagnosis of significant lesion and physiologic complexity and include (but is not limited to) common truncus lesions and double outlet right ventricle.

Also included in this grouping are diagnoses which could have been included in other diagnostic grouping but did not have operative coding which would have confirmed their post-operative anatomy such as TGA with no procedural descriptor.

As such, this is a heterogenous group of patients with CHD with various underlying cardiac lesions that will behave very differently, with different physiology and natural history of their underlying cardiac lesions. Nonetheless, they are CHD lesions and to omit them entirely or form smaller groups would not be appropriate.

The diagnostic codes included to describe these lesions are shown in Table 4-21.

Table 4-21 ICD codes describing complex congenital lesions

ICD Version	Code	Descriptor
9	745.0	Common Truncus Absent septum between aorta and pulmonary artery Communication (abnormal) between aorta and pulmonary artery Aortic septal defect Common aortopulmonary trunk Persistent truncus arteriosus
	745.11	Double outlet right ventricle (DORV) Dextratransposition of aorta Incomplete transposition of great vessels Origin of both great vessels from right ventricle

		Taussig-Bing syndrome or defect
	745.19	Other, unspecified (under TGA)
	745.3	Common ventricle Single ventricle
	746.01	Congenital pulmonary valve atresia
	746.1	Tricuspid atresia Absence of tricuspid valve
10	Q20.0	Common arterial trunk Persistent truncus
	Q20.1	Double outlet right ventricle Taussig-Bing syndrome
	Q20.2	Double outlet left ventricle
	Q20.4	Double inlet left ventricle Common ventricle Cor triloculare biatriatrum Single ventricle
	Q21.4	Aortopulmonary septal defect Aortic septal defect Aortopulmonary window
	Q22.0	Pulmonary valve atresia
	Q22.4	Congenital tricuspid stenosis Tricuspid atresia
	Q22.6	Hypoplastic right heart syndrome
	Q25.5	Atresia of the pulmonary artery

Operative codes associated with the intervention and repair of these lesions are shown in Table 4-22.

Table 4-22 OPCS codes describing procedural repairs of complex congenital lesions

OPCS Code	Descriptor
K06.3	Left ventricle to aorta tunnel with right ventricle to pulmonary trunk direct anastomosis
K06.4	Double switch
K08.1	Repair of double outlet ventricle with intraventricular channel
K08.3	Repair of double outlet right ventricle
K08.4	Repair of double outlet left ventricle
K08.8	Repair of double outlet ventricle, not specified
K08.9	Repair of double outlet ventricle, not otherwise specified
L01.4	Correction of persistent truncus arteriosus
L01.4	Correction of AP window
L69.2	Pulmonary unifocalisation

4.2.3.13 Other Lesions

ICD and OPCS codes in this group describe individuals that have diagnostic or procedural coding which is not specific to any of the aforementioned lesion categories. The nature of the diagnostic or procedural coding is either vague with respect to the underlying lesion or to the region of the heart that is affected. Due to heterogenous nature of the lesions that will be included in this group I will be unable it in the lesion complexity grouping which will be described in Chapter 4.4

The diagnostic codes included to describe these lesions are shown in Table 4-23.

Table 4-23 ICD codes describing other lesions

ICD Version	Code	Descriptor
9	745.8	Other bulbus cordis and cardiac septal closure defects
	745.9	Unspecified defect of septal closure
	746.82	Cor triatriatum
	746.84	Other obstructive anomalies of the heart
	746.85	Coronary artery anomalies
	746.9	Unspecified anomaly of heart
	747.4	Anomalies of great veins (absence and persistence of cavae)
	747.41	Total anomalous pulmonary venous connection Total anomalous pulmonary venous return (TAPVR) - Subdiaphragmatic - Supradiaphgragmatic
	747.3	Anomalies of pulmonary artery Agenesis of pulmonary artery Anomaly of PA Coarctation of PA Hypoplasia of PA Stenosis of PA Pulmonary AV aneurysm
	745.7	Cor biloculare Absence of atrial and ventricular septa
10	Q20.8	Other malformations of cardiac chambers and connections
	Q20.9	Malformations of cardiac chambers and connections, unspecified
	Q21.8	Other malformations of cardiac septa
	Q21.9	Malformations of cardiac septal, unspecified
	Q25.8	Other malformations of great arteries
	Q25.9	Malformations of great arteries, unspecified

	Q26.4	Anomalous pulmonary venous connection, unspecified
	Q24.5	Malformation of coronary vessels
	Q20.6	Isomerism of atrial appendages Isomerism of atrial appendages with aspelnia or polysplenia
	Q26.2	Total anomalous pulmonary venous drainage
	Q24.2	Cor triatriatum

Operative codes associated with the intervention and repair of these lesions are shown in Table 4-24.

Table 4-24 OPCS codes describing procedural repairs of other lesions

OPCS Code	Descriptor
K12	Surgical and percutaneous closure of unspecified septum
K13	Percutaneous repair of unspecified septum
K14	Open atrial septostomy
K15	Closed atrial septostomy
K18	Creation and revision of cardiac conduits
L05	Systemic arterial to pulmonary arterial shunt
L06	Creation or takedown of aorta to pulmonary arterial connection
L07	Creation, closure or dilatation of subclavian artery to pulmonary arterial shunt
L08	Creation or percutaneous intervention to subclavian artery to pulmonary artery shunt
L12	Application, adjustment or removal of pulmonary artery band
L70.8	Intervention to major systemic to pulmonary collateral arteries and unifocalisation
K20.3	Repair of cor triatriatum
K20.4	Repair of coronary sinus
K20.9	Unspecified repair of septum
K07.8	Other repair of TAPVD, specified
K07.9	Other repair of TAPVD, unspecified
K07.1	Correction of total anomalous pulmonary venous connection to supracardiac vessel
K07.2	Correction of TAPVD to coronary sinus
K07.3	Correction of TAPVD to infradiaphragmatic vessel

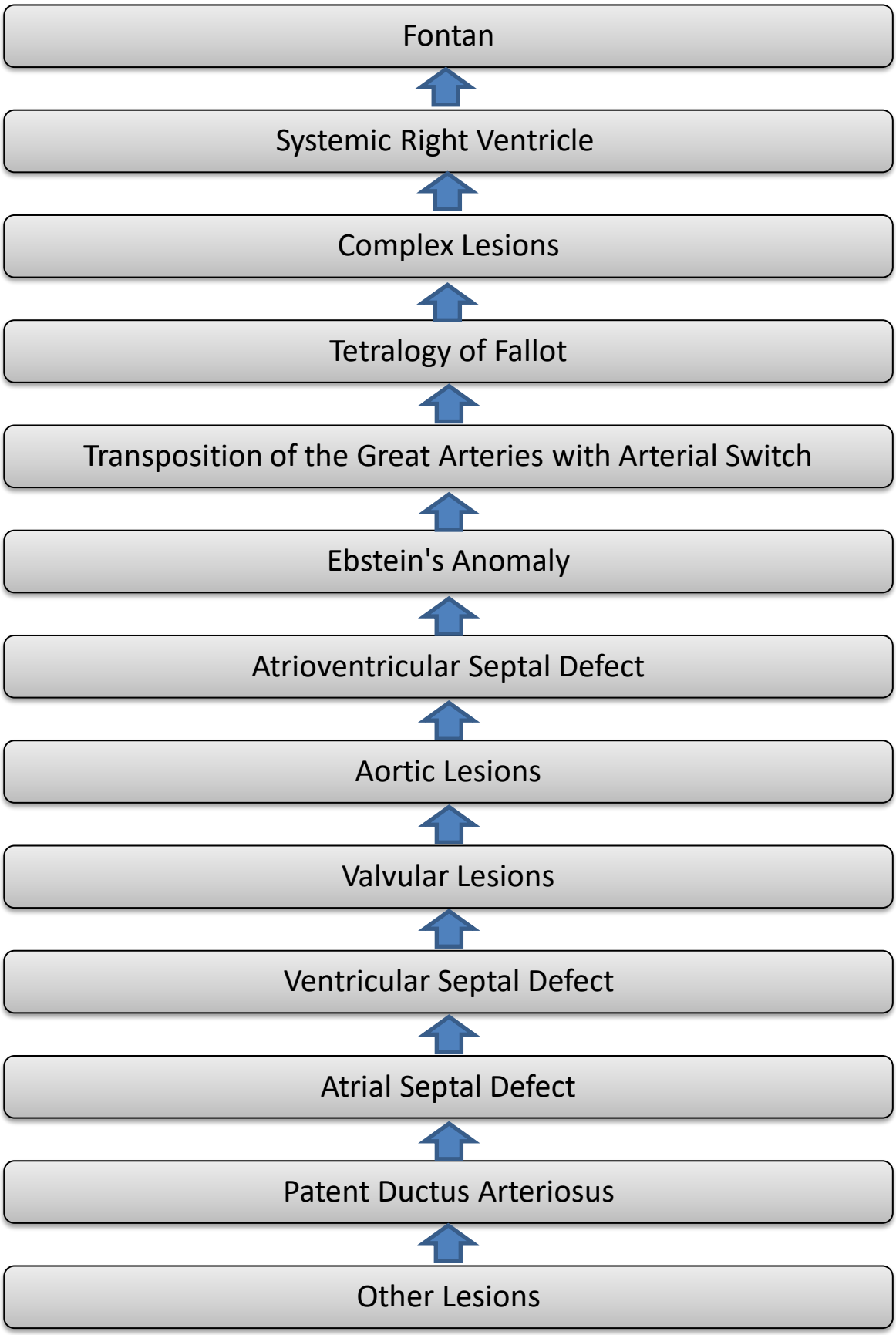
4.2.4 Excluded ICD codes

The codes in ICD 9 (747) and ICD 10 (Q26, Q27 & Q28) that describe congenital malformations of peripheral and central vascular malformations outside the great vessels were excluded. These descriptive codes, although congenital lesions, are not cardiac in nature. The only exception is that if there was another ICD or OPCS descriptor that described a CHD lesion as listed above, in any position in their diagnosis or procedural list that would have led to their inclusion in any of the 13 groups outlined.

4.3 CHD Lesion Hierarchy

Many individuals with CHD will have more than one underlying CHD lesion that may involve multiple ICD diagnostic codes to describe their cardiac anatomy. To ensure that individuals with more than one CHD diagnosis are grouped along with the lesion of greatest complexity, a hierarchical system of grouping is required. For example, take a patient with Ebstein's anomaly and associated secundum atrial septal defect. They would have an ICD codes of Q21.1 (secundum ASD) and Q22.5 (Ebstein's anomaly). The diagnostic code of highest lesion complexity here is Q22.5, and so this individual should be included in the Ebstein's grouping and not along with the secundum ASD groupings. To allow this assignment of a major diagnosis, a grouping hierarchy was established. This can be found in Figure 4-1.

Figure 4-1 Major CHD diagnosis group hierarchy



4.4 CHD Lesion Complexity

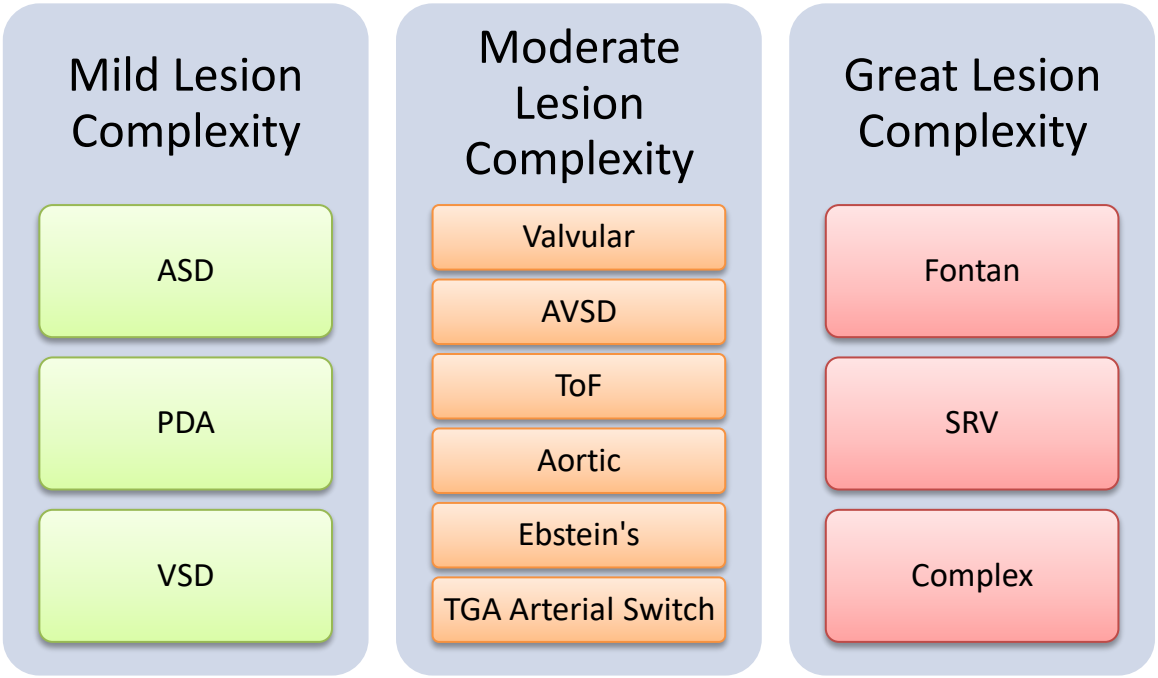
The terminology of complexity will be used in this thesis instead of severity, as this can often be ambiguous (e.g. when describing the degree of ventricular dysfunction or valvular regurgitation).

The most commonly utilised stratification of CHD lesion complexity is that outlined by Task Force 1 of the 32nd Bethesda Conference [23], whereby lesions are collected together in lesions of mild, moderate and great complexity.

The limitations of using hospitalisation diagnostic and operational coding are that the nuances in the heterogeneity of CHD can be difficult to ascertain from population-level data. For example, in the Bethesda classification a secunudm ASD with significant left-to-right shunt or any sinus venosus defect would be classified as a lesion of moderate complexity. Whereas those secundum ASDs of no haemodynamic significance (or previously repaired) would be classified as mild complexity. Without access to notes to quantify shunt, and with access only to OPCS and ICD (code Q21.1) that encompasses all coronary sinus defects, secundum ASDs, PFOs and sinus venosis defects, this classification is made more difficult.

To allow for this I have had to adapt, and simplify, the decision process on classification complexity from the information available, although I have continued to utilise the overall complexity groupings of mild, moderate and great. The diagnoses included in each complexity groupings are demonstrated in Figure 4-2.

Figure 4-2 CHD diagnoses in each lesion complexity grouping



4.5 Age Terminology Classification

Various age groupings will be used in this thesis to allow adequate comparisons between individuals of similar age groups. The following descriptions will be used throughout this thesis to describe various age groups:

a) Infants – age <1 years

b) Children – age 1 – 15 years

c) Paediatrics – age <16 years

d) Adults – age ≥16 years

e) Younger adults – age 20 – 64 years

f) Older adults – age ≥65 years

4.6 Index Hospitalisations

Some patients will have more than one hospitalisation within the study period. Although all hospitalisations for each patient are included, the year of hospitalisation (index event) is recorded in the year where an ICD or OPCS code

describing a CHD lesion or procedure first appears in their diagnostic list. However, complexity hierarchy will be applied to all SMR entries for that patient to ensure that the CHD diagnosis that best describes that patient is associated with their index hospitalisation.

4.7 Statistics

All statistical tests were carried out using STATA 14 (StataCorp. 2015. Stata Statistical Software: Release 14. College Station, TX: StataCorp LP). Continuous variables are expressed as mean and standard deviation for normally distributed data, whilst median was used for non-normally distributed data. A two-tailed p value of <0.05 was considered to be of statistical significance.

Scottish population estimates were accessed from the National Records of Scotland online portal.[86] This freely-accessible online resource publishes annual population time series data from 1981 to the present. This is accessible by single year of age, sex and Health Board of residence. This data was used to calculate hospitalisation rates in relation to the total Scottish population. Hospitalisation rates will be displayed as hospitalisation rates per 100 000 of the age matched Scottish population, unless otherwise stated. Age matched hospitalisation rates were also used to infants, (age <1), children (age 1-15), paediatric (age<16) and adults (age ≥16).

Temporal trends of hospitalisation rates were quantified by annual percentage change (APC) using Joinpoint Regression Program (Version 4.8.0.1-April 2020; Statistical Methodology and Applications Branch, Surveillance Research Programme, National Cancer Institute).[87]

There is precedent of using the joinpoint model to analyse temporal trends of index hospitalisations in Scotland. Jhund et al.[88] investigated the changes in index hospitalisation of heart failure between 1986 and 2003. The authors used diagnostic (ICD) descriptors to identify a study population of index heart failure hospitalisations in SMR01 records. APC is also routinely used by the National Cancer Institute to report temporal changes in cancer incidence which is reported annually.[89]

When using APC the annual rates are assumed to change at a constant percentage of the index hospitalisation rate of the previous year. Rates that change at a constant percentage each year will have a linear trend. The advantage of using APC to characterise trends is that it is a measure that is comparable across different scales as well as being easy to understand. This means that if one or more CHD lesions have a significantly higher number of index hospitalisations compared to another lesion, the APC of the hospitalisation rates can still be used for both CHD lesions for comparison. One needs to consider that a single APC may not always be reasonable to describe trends over an entire series of data. For example, the index hospitalisation rates for VSD may gradually decrease for a period of several years before decreasing significantly before levelling off. The method of analysis I have used allows changes in trends to be detected.

The joinpoint model uses statistical criteria to determine when and how often the APC changes. This is achieved by fitting the simplest model that the data allows. The programme starts with the minimum number of joinpoints (e.g. 0 join points, which is a straight line) and tests if more joinpoints are statistically significant and must be added to the model, thus allowing a test to analyse if a change in trend is statistically significant. Confidence intervals are then calculated using a linear regression model. An increasing APC was determined if APC estimation and the lower boundary of the 95% CI was >0. A decreasing APC was determined if the APC and the upper boundary of the 95% CI are both <0. Where differences between APCs are discussed, they are compared using overlap of the 95% confidence intervals and are considered to be significant if the confidence intervals of the APC to not overlap.

5 Lesions and Severity

5.1 Introduction

In this chapter I analyse index hospitalisations and index hospitalisation rates in patients with a diagnosis of CHD. I include patients of all ages. Grouping specific lesions of similar complexity together in mild, moderate and great will allow me to make comparisons with similar published data on CHD hospitalisation and epidemiology.

Lesions will be grouped depending on cardiac anatomy and/or physiology as described below:

- Atrial Septal Defects (ASD)
- Patent Ductus Arteriosus (PDA)
- Ventricular Septal Defects (VSD)
- Atrio-Ventricular Septal Defects (AVSD)
- Aortic Anomalies (Aortic)
- Ebstein's Anomaly (Ebstein's)
- Tetralogy of Fallot (ToF)
- Transposition of the Great Arteries (TGA) with Arterial Switch
- Systemic Right Ventricle (SRV)
- Fontan repair (Fontan)
- Congenital valvular lesions, not elsewhere classified (Valvular)
- Complex lesions, not elsewhere classified (Complex)
- Other lesions, not elsewhere classified (Other)

Lesions of mild complexity will include diagnoses of ASD, VSD and PDA. Lesions of great complexity will include diagnoses of Complex lesions, Fontan and SRV. Lesions of moderate complexity will contain the remainder of diagnoses not otherwise grouped.

5.2 Methods

The methods used within this Chapter are outlined in Chapter 4 Methods. The only change is with reporting of hospitalisation rate. Index hospitalisations are indexed to the general Scottish population for each year. Due to the small numbers observed for some lesions, the index hospitalisation rate used is adjusted to hospitalisations per 1 000 000 of the Scottish population each year.

5.3 Results

5.3.1 Baseline Characteristics

A total of 17 990 patients has an index hospitalisation with a diagnosis of CHD during the observed period of 1990 to 2015.

A table summarising the baseline characteristics of all individuals as well as those for specific lesions is found in Table 5-1.

Table 5-1 Baseline characteristics of all patients and specific CHD lesions

	CHD Lesions								
	All	ASD	PDA	VSD	AVSD	Aortic	Ebstein's	ToF	TGA
Hospitalisations, n (%)	17 990 (100)	4 184 (23.2)	1 707 (9.5)	2 567 (14.3)	866 (4.8)	2 003 (11.1)	120 (0.7)	781 (4.3)	220 (1.2)
Adults (age ≥16)	8 482 (47.1)	3 090 (73.9)	104 (6.1)	839 (32.7)	201 (23.2)	1 168 (58.3)	71 (59.2)	109 (14.0)	0 (0)
Children (age <16)	9 508 (52.9)	1 094 (26.1)	1 603 (93.9)	1 728 (73.3)	665 (76.8)	835 (41.7)	49 (40.8)	672 (86.0)	220 (100.0)
Median age, years	25	37	4	18	11	39	26	5	0
Sex, n (%) [p value]									
Female	9 004 (50.1) [0.79]	2 397 (57.3) [<0.05]	961 (56.3) [<0.05]	1 255 (48.9) [0.27]	494 (57.0) [<0.05]	911 (45.5) [<0.05]	73 (60.8) [<0.05]	332 (42.5) [<0.05]	69 (31.4) [<0.05]
Male	8 986 (49.9)	1 787 (42.7)	746 (43.7)	1 312 (51.1)	372 (43.0)	1 092 (54.5)	47 (39.2)	449 (57.5)	151 (68.6)
SIMD Quintile, n (%) [p value]									
1 (most deprived)	4 849 (27.2) [<0.05]	1 113 (26.8) [<0.05]	554 (32.6) [<0.05]	701 (27.7) [<0.05]	233 (27.0) [<0.05]	496 (24.9) [<0.05]	27 (22.7) [0.46]	213 (27.5) [<0.05]	54 (24.5) [0.10]
2	3 827 (21.4)	882 (21.2)	366 (21.6)	545 (21.5)	195 (22.6)	432 (21.7)	17 (14.3)	176 (22.7)	33 (15.0)
3	3 339 (18.7)	757 (18.2)	287 (16.9)	468 (18.4)	161 (18.7)	399 (20.0)	24 (20.2)	151 (19.5)	54 (24.5)
4	3 019 (16.9)	704 (16.9)	265 (15.6)	433 (17.1)	133 (15.4)	331 (16.6)	26 (21.8)	122 (15.8)	33 (15.0)
5 (least deprived)	2 818 (15.8) [<0.05]	703 (16.9) [<0.05]	224 (13.3) [<0.05]	388 (15.3) [<0.05]	141 (16.3) [<0.05]	334 (16.8) [<0.05]	25 (21.0) [0.78]	112 (14.5) [<0.05]	46 (21.0) [0.71]

	CHD Lesions					
	All	SRV	Fontan	Valvular	Complex	Other
Hospitalisations, n (%)	17 990 (100)	123 (0.7)	216 (1.2)	2 069 (11.5)	1 618 (9.0)	1 516 (8.4)
Adults (age ≥16)	8 482 (47.1)	15 (12.2)	17 (7.9)	1 304 (63.0)	348 (21.5)	1 216 (80.2)
Children (age <16)	9 508 (52.9)	108 (87.8)	199 (92.1)	765 (37.0)	1 270 (78.5)	300 (19.8)
Median Age, years	25	6	4	35	4	35
Sex, n (%) [p value]						
Female	9 004 (50.1) [0.79]	50 (40.7) [<0.05]	76 (35.2) [<0.05]	877 (42.4) [<0.05]	787 (48.6) [0.26]	722 (47.6) [0.06]
Male	8 986 (49.9)	73 (59.3)	140 (64.8)	1 192 (57.6)	831 (51.4)	794 (52.4)
SIMD Quintile, n (%) [p value]	17 852 (99.2)					
1 (most deprived)	4 849 (27.2) [<0.05]	36 (29.8) [<0.05]	78 (36.6) [<0.05]	495 (24.1) [<0.05]	451 (28.2) [<0.05]	398 (26.5) [<0.05]
2	3 827 (21.4)	27 (22.3)	44 (20.7)	429 (20.9)	350 (21.9)	331 (22.0)
3	3 339 (18.7)	22 (18.2)	32 (15.0)	405 (19.7)	311 (19.4)	268 (17.8)
4	3 019 (16.9)	19 (15.7)	26 (12.2)	390 (19.0)	261 (16.3)	275 (18.3)
5 (least deprived)	2 818 (15.8) [<0.05]	17 (14.0) [0.09]	33 (15.5) [0.10]	335 (16.3) [<0.05]	228 (14.2) [<0.05]	232 (15.4) [<0.05]

Atrial septal defects were the most common lesion identified, representing 23.2% of the total index hospitalisations. Ebstein's anomaly and systemic right ventricles were the lesions that were least frequently observed, each representing 0.7% of the total study cohort.

The median age at presentation for all index hospitalisations is 25 years. The youngest mean age of index hospitalisation was observed in patients with TGA and arterial switch and Fontan, ages 0 and 4 respectively. The oldest mean age at index hospitalisation was observed in aortic lesions and atrial septal defects, ages 39 and 37 respectively.

Overall, there were more index hospitalisations in women (n=9 004, 50.1%) compared with men (n= 8 986, 49.9%), although this difference was not of significant (p=0.79). Women had more index hospitalisations of Ebstein's (60.8%, p<0.05), ASD (57.3%, p<0.05), PDA (56.3%, p<0.05) and AVSD (57.0%, p<0.05) compared to men. Men had the largest proportion of Fontan (64.8%, p<0.05), valvular (57.6%, p<0.05), aortic (54.5%, p<0.05), ToF (57.5%, p<0.05), TGA (68.6%, p<0.05) and SRV (59.3%, p<0.05) index hospitalisations. There was no difference between the sexes for index hospitalisations of VSD, complex and other lesions.

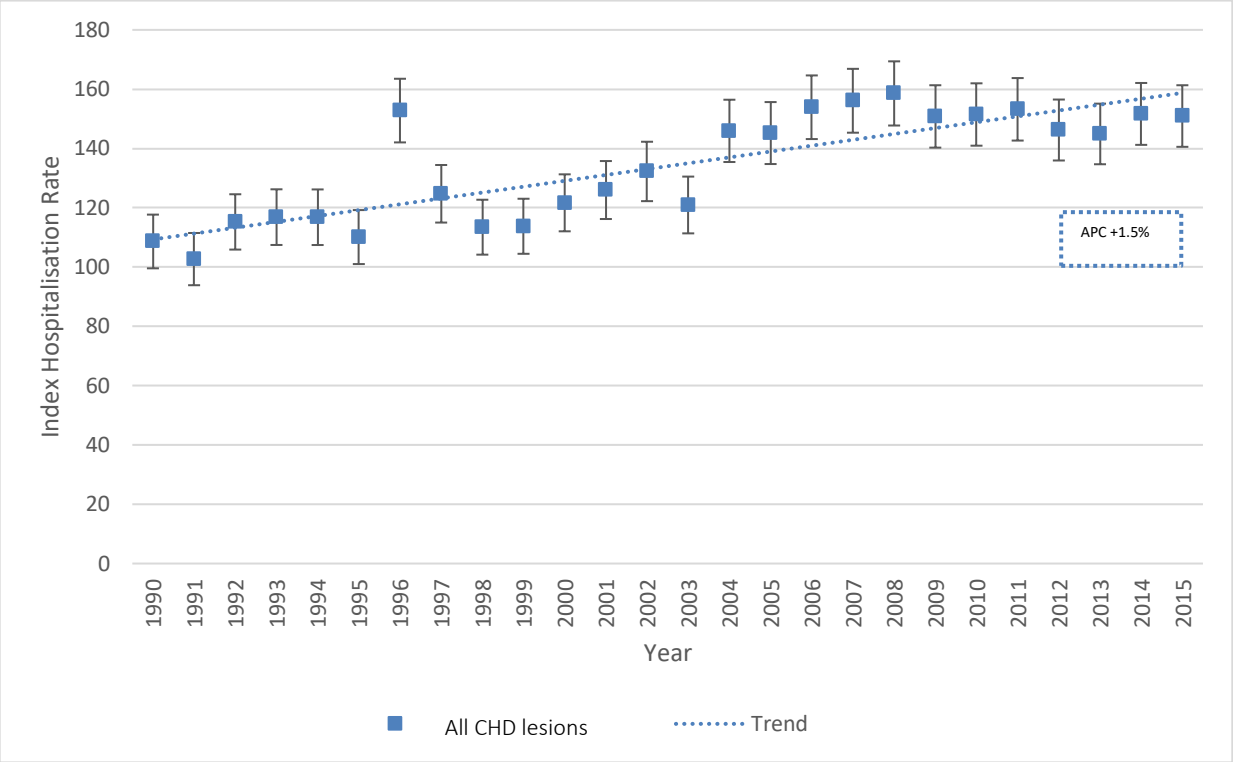
Measures of deprivation (SIMD) were available for 17 852 patients (missing n=138, 0.8%) with an index hospitalisation. SIMD1 (most deprived) had the largest number of index hospitalisations (n=4 849, 27.2%), p<0.05. Whereas SIMD5 (least deprived) had the least number of index hospitalisations (n=2 818, 15.8%), p<0.05.

The yearly index hospitalisation rate of patients with CHD per 1 000 000 of the Scottish population is shown in Table 1 of Appendix A.

The index hospitalisation rate ranged from 108.6 patients per 1 000 000 of the Scottish population admitted in the year 1990, to 150.9 in the year 2015. This is an increase of 42.3 (28.0%). The hospitalisation rate ranged from a minimum of 102.7 (1991) to a maximum 158.6 (2008) per annum.

The yearly index hospitalisation rate per 1 000 000 of the population is shown in Figure 5-1.

Figure 5-1 Index hospitalisation rate per annum for individuals with CHD



Index hospitalisation rate per annum for individuals with CHD expressed as rate per 1 000 000 general population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

There was a 1.5% (95% CI 1.0 - 1.9%, $p<0.05$) annual increase in the index hospitalisation rate for CHD.

5.3.2 Anatomical and/or Physiological Grouping

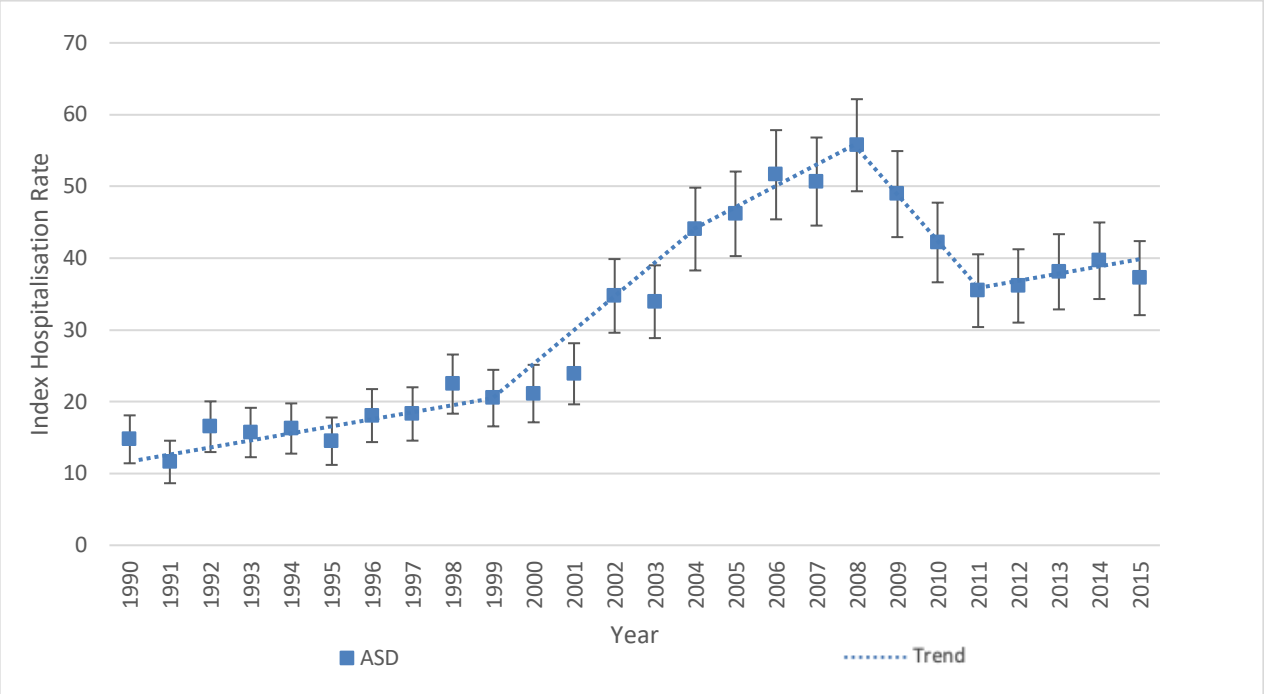
5.3.2.1 Atrial Septal Defects

4 184 patients with a diagnosis of ASD had an index hospitalisation within the 25-year period. This represents 23.3% of the total number of patients with CHD lesions admitted to hospital. The number of ASD index hospitalisations per year ranged from 74 – 290 per annum.

The index hospitalisation rate per annum for individuals with a diagnosis of ASD per 1 000 000 of the general population is shown in Table 2 of Appendix A. The index hospitalisation rate for ASD changed from 14.8 to 37.2 per 1 000 000. This

represents as increase of 22.5 (152%). The index hospitalisation rate per annum is displayed in Figure 5-2.

Figure 5-2 Index hospitalisation rate per annum for individuals with ASD



Index hospitalisation rate per annum for individuals with ASD expressed as rate per 1 000 000 general population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

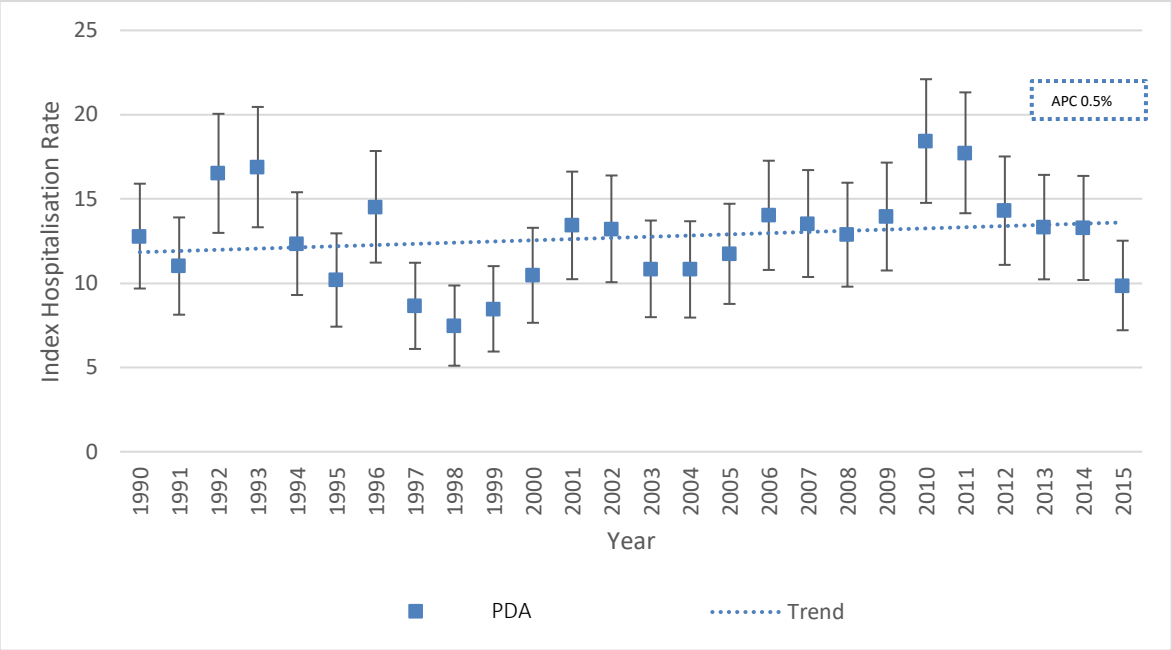
The trend line for index ASD hospitalisation rates vary over time, with 4 join points. Between years 1990 to 1999 there was a 4.9% (95%CI 2.1 - 7.8%, p <0.05) annual increase in the index hospitalisation rate. Between 2000 and 2004 there was an annual increase in index hospitalisation rate of 19.2% (95%CI 3.9 - 36.7%, p<0.05). Thereafter there was no change in the APC between 2004 and 2008 (6.2% (95%CI -4.3 – 17.9, p=0.2)), 2008 and 2011 (13.5% (95% CI -30.1 – 7.1 95, p =0.2)) and 2011 and 2015 (1.7% (95% CI -5.6 – 9.5), p=0.6)).

5.3.2.2 Patent Ductus Arteriosus

1 707 patients with PDA had an index hospitalisation over the observed 25-year period. This represents 9.5% of the total number of patients with CHD lesions hospitalised. The number of index hospitalisations per year ranged from 38 – 97.

The index hospitalisation rate per year with a diagnosis of PDA per 1 000 000 of the population is shown in Table 3, Appendix 1 and is displayed in Figure 5-3.

Figure 5-3 Index hospitalisation rate per annum for individuals with PDA



Index hospitalisation rate per annum for individuals with PDA expressed as rate per 1 000 000 general population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

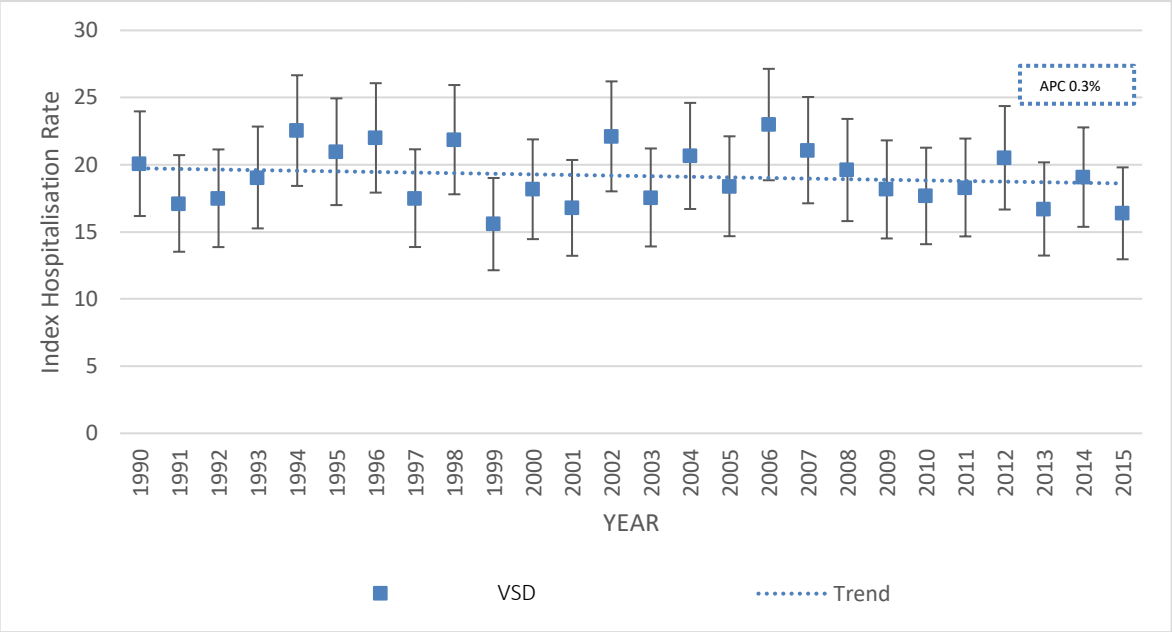
There was no change in the annual index hospitalisation rate over the study period. The APC was 0.5% (95% CI -0.7 - 1.6%, p=0.4).

5.3.2.3 Ventricular Septal Defect

2 567 patients with VSD had an index hospitalisation within the 25-year period. This represents 14.3% of the total number of patients with CHD lesions hospitalised. Yearly hospitalisations ranged from 79 – 118.

The index hospitalisation rate per 1 000 000 of the population with a diagnosis of VSD ranged from 20.1 in 1990 to 16.4 in 2015. The index hospitalisation rate per year with a diagnosis of VSD indexed to 1 000 000 of the population is shown in Table 4, Appendix 1 and is displayed in Figure 5-4.

Figure 5-4 Index hospitalisation rate per annum for individuals with VSD



Index hospitalisation rate per annum for individuals with VSD expressed as rate per 1 000 000 general population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

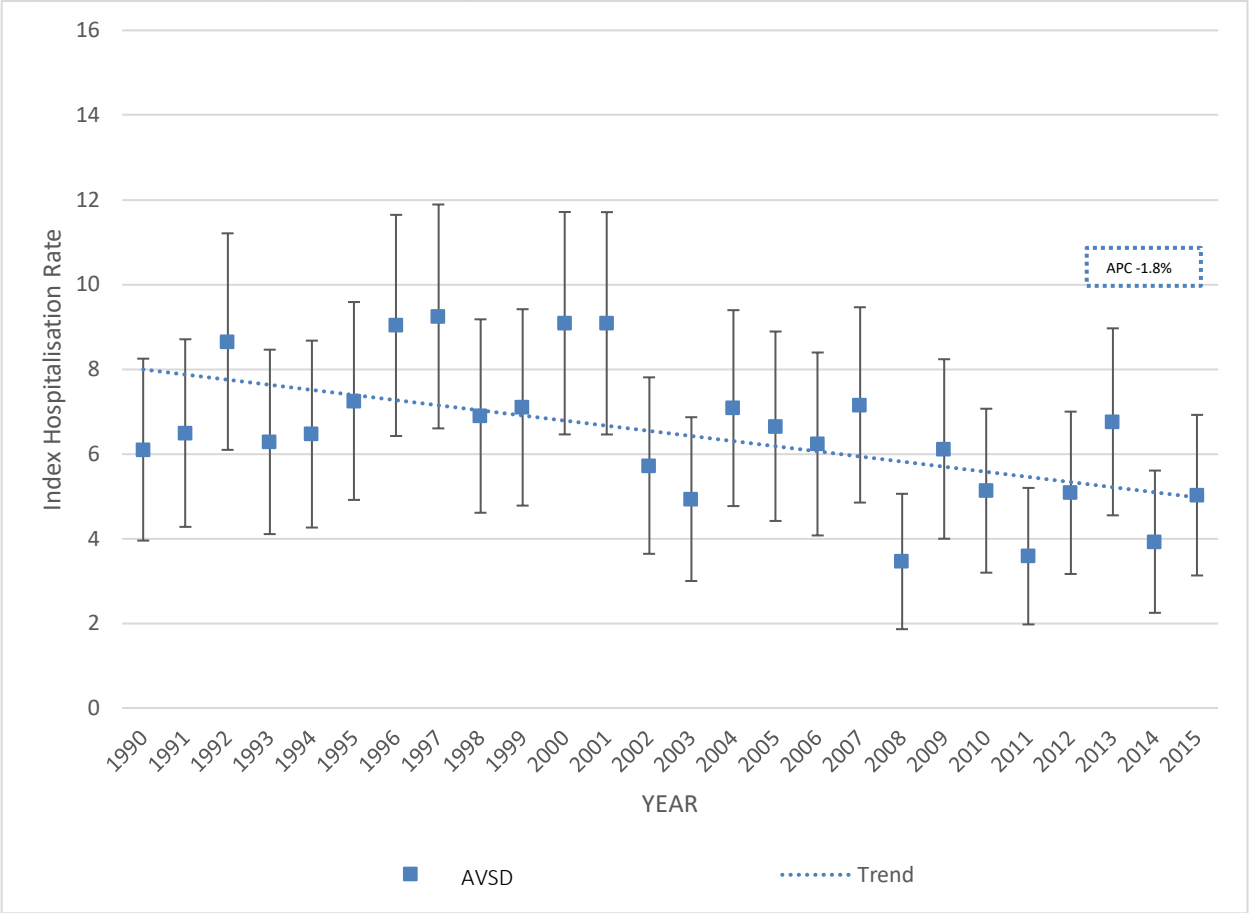
There was no change in the annual index hospitalisation rate over the study period. The APC was 0.3% (95% CI -0.9 – 0.3%, p=0.4).

5.3.2.4 Atrioventricular Septal Defects

886 patients with AVSD had an index hospitalisation within the 25-year period. This represents 4.8% of the total number of patients with CHD lesions hospitalised within this period. The number of hospitalisations ranged from 18 – 47 per year.

The index hospitalisation rate per 1 000 000 of the population with a diagnosis of AVSD was 6.1 in 1990 compared to 5.0 in 2015. The index hospitalisation rate per year with a diagnosis of AVSD indexed to 1 000 000 of the population is shown in Table 5, Appendix A and is displayed in Figure 5-5.

Figure 5-5 Index hospitalisation rate per annum for individuals with AVSD



Index hospitalisation rate per annum for individuals with AVSD expressed as rate per 1 000 000 general population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

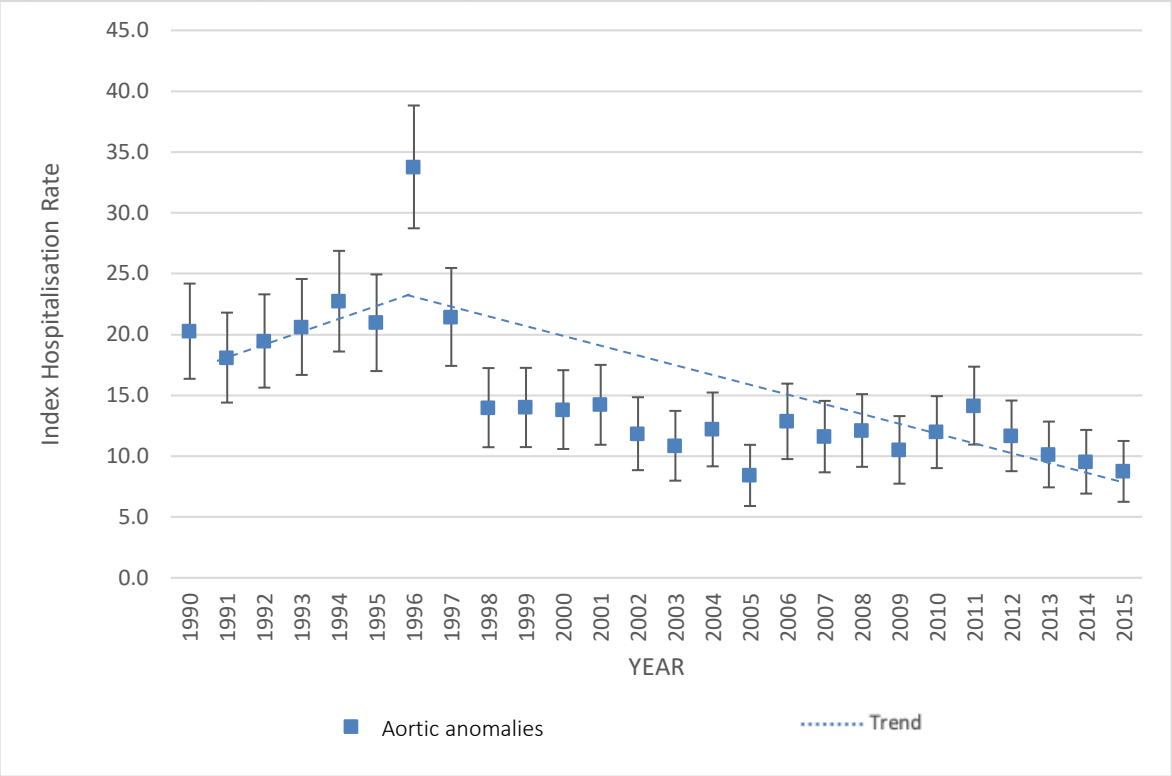
There was a 1.8% (95% CI -3.0 - 0.6%, p<0.05) annual decrease in the index hospitalisation rate for AVSD.

5.3.2.5 Aortic anomalies

2 003 patients with aortic anomalies had an index hospitalisation within the 25-year period. This represents 11.3% of the total number of patients with CHD lesions admitted to hospital. The number of index hospitalisations ranged from 47 – 172.

The index hospitalisation rate per 1 000 000 of the population with a diagnosis of aortic anomalies admitted in 1990 is 20.3 compared with 8.8 in 2015. The index hospitalisation rate per year with a diagnosis of aortic anomalies indexed to 1 000 000 of the population is shown in Table 6, Appendix 1 and is displayed in Figure 5-6.

Figure 5-6 Index hospitalisation rate per annum for individuals with aortic anomalies



Index hospitalisation rate per annum for individuals with aortic anomalies expressed as rate per 1 000 000 general population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

There was 1 joinpoint for the trend line in the year 1995. Between 1990 and 1995 there was no change in the annual index hospitalisation rate, the APC was 2.8% (95%CI-10.0 – 17.5%, p=0.7). However, between 1995 and 2015, there was a 4.6% (95% CI -.06% - -2.8%, p<0.05) annual decrease in the index hospitalisation rate for aortic anomalies. The year 1996 appears to be an outlier within surrounding years and this will be discussed later in this Chapter 5.4 Discussion.

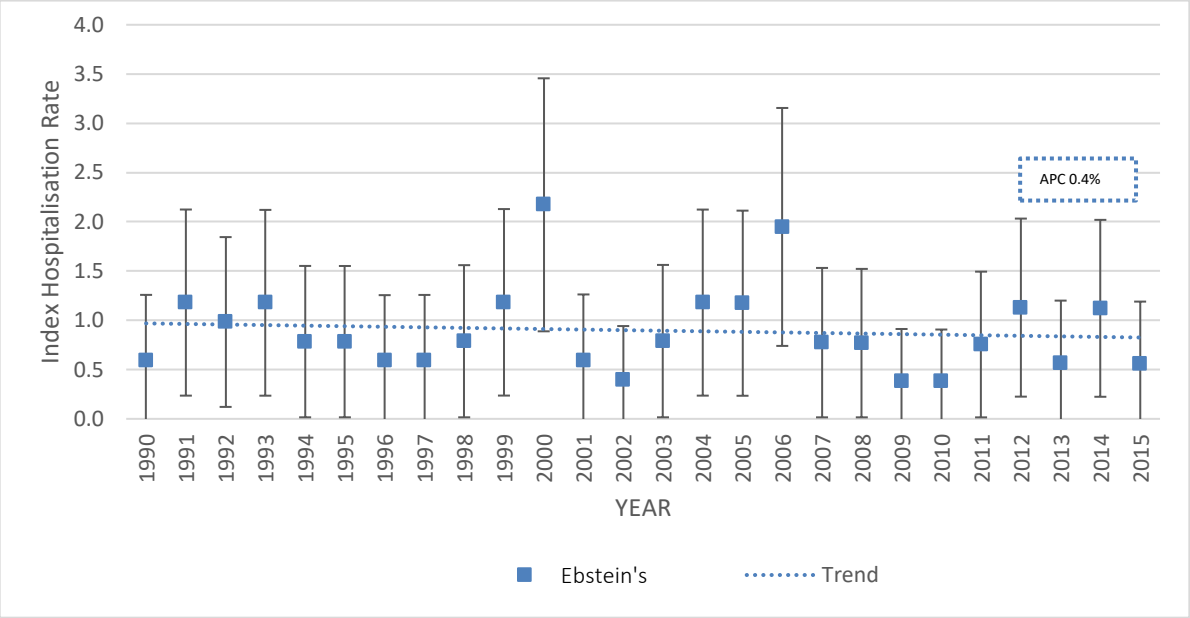
5.3.2.6 Ebstein's Anomaly

120 patients with Ebstein's anomaly had an index hospitalisation within the 25-year period. This represents 0.7% of the total number of patients with CHD lesions admitted to hospital. The number of index hospitalisations per year ranged from 2 – 11.

The index hospitalisation rate per 1 000 000 of the population with a diagnosis of Ebstein's anomaly admitted in 1990 is 0.6, which is the same rate that was observed in 2015. The index hospitalisation rate per year with a diagnosis of

Ebstein's anomaly indexed to 1 000 000 of the population is shown in Table 7, Appendix 1 and is displayed in Figure 5-7.

Figure 5-7 Index hospitalisation rate per annum for individuals with Ebstein's anomaly



Index hospitalisation rate per annum for individuals with Ebstein's anomaly expressed as rate per 1 000 000 general population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

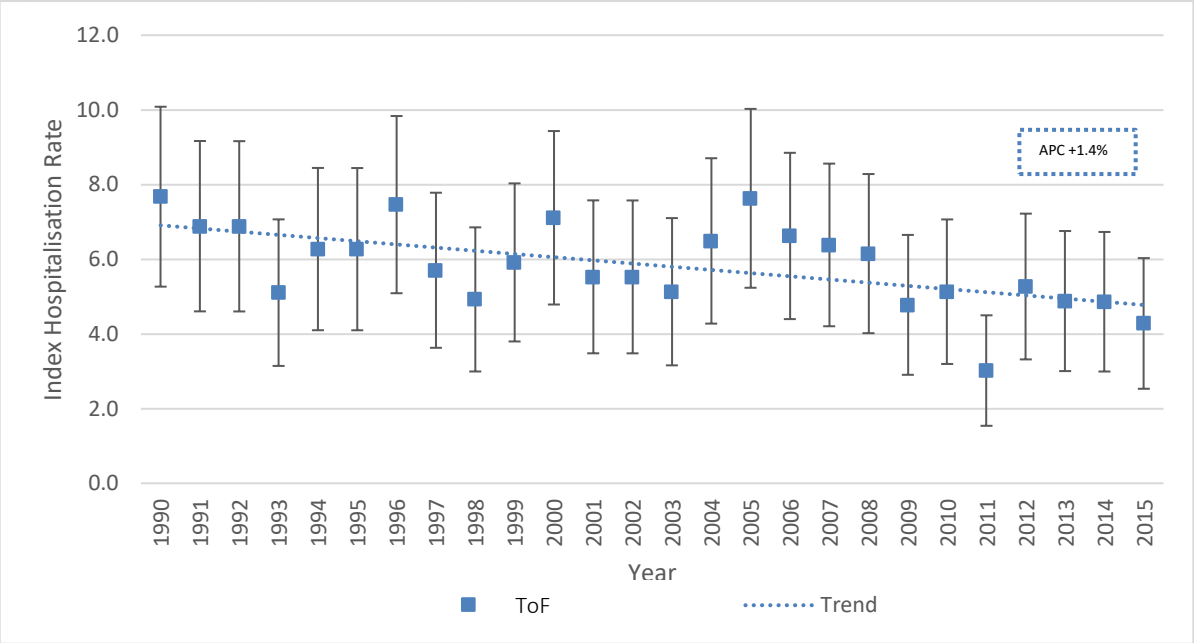
There was no change in the annual index hospitalisation rate for Ebstein's anomaly over the study period, the APC was 0.4% (95% CI -3.0 - 2.2%, p=0.7).

5.3.2.7 Tetralogy of Fallot

781 patients with ToF had an index hospitalisation within the study period. This represents 4.3% of the total number of patients with CHD lesions admitted to hospital. The number of index hospitalisations per year ranged from 16 - 39.

The index hospitalisation rate per 1 000 000 of the population with a diagnosis of ToF admitted in 1990 is 0.6, which is the same rate that was observed in 2015. The index hospitalisation rate per year with a diagnosis of ToF indexed to 1 000 000 of the population is shown in Table 8, Appendix 1 and is displayed in Figure 5-8.

Figure 5-8 Index hospitalisation rate per annum for individuals with ToF



Index hospitalisation rate per annum for individuals with ToF expressed as rate per 1 000 000 general population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

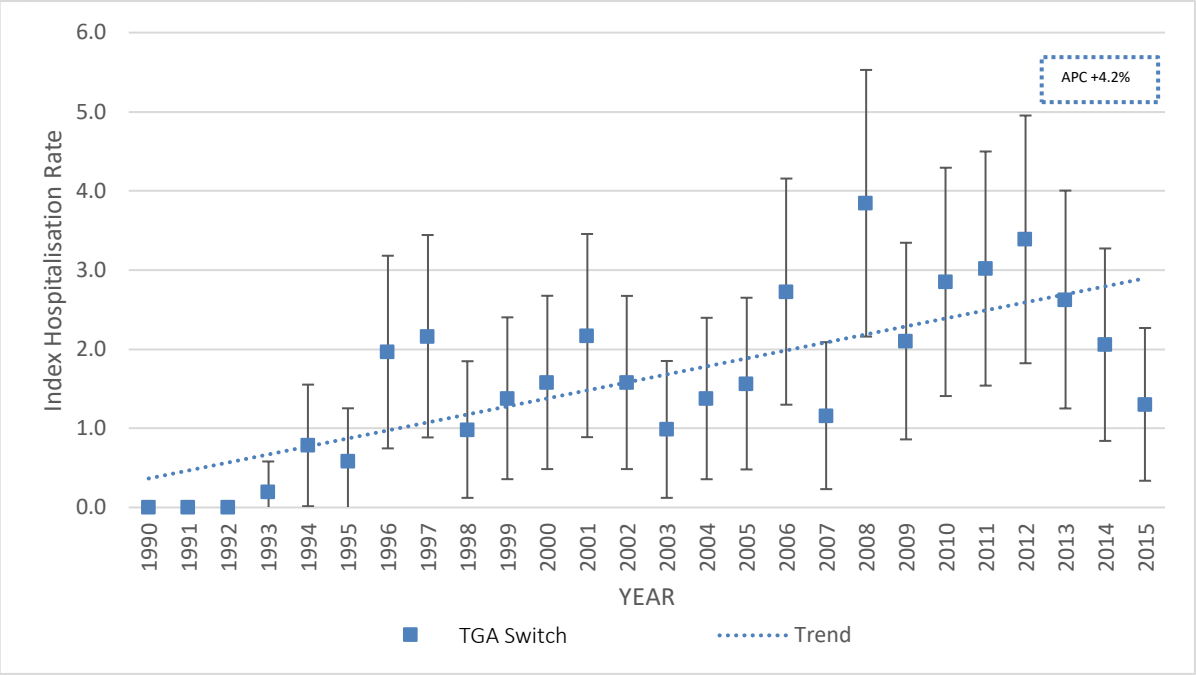
There was a 1.4% (95% CI -2.3 - -0.5%, p<0.05) annual decrease in the index hospitalisation rate for ToF.

5.3.2.8 Transposition of the Great Arteries with Arterial Switch (TGA Switch)

220 patients with TGA Switch had an index hospitalisation within the 25-year period. This represents 1.2% of the total number of patients with CHD lesions admitted to hospital. The number of index hospitalisations per year ranged from 0 – 20 per year.

The index hospitalisation rate per 1 000 000 of the population with a diagnosis of TGA Switch admitted in 1990 is 0 compared with 1.3 in 2015. The index hospitalisation rate per year with a diagnosis of TGA Switch indexed to 1 000 000 of the population is shown in Table 9, Appendix 1 and is also displayed in Figure 5-9.

Figure 5-9 Index hospitalisation rate per annum for individuals with TGA Switch



Index hospitalisation rate per annum for individuals with TGA Switch expressed as rate per 1 000 000 general population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

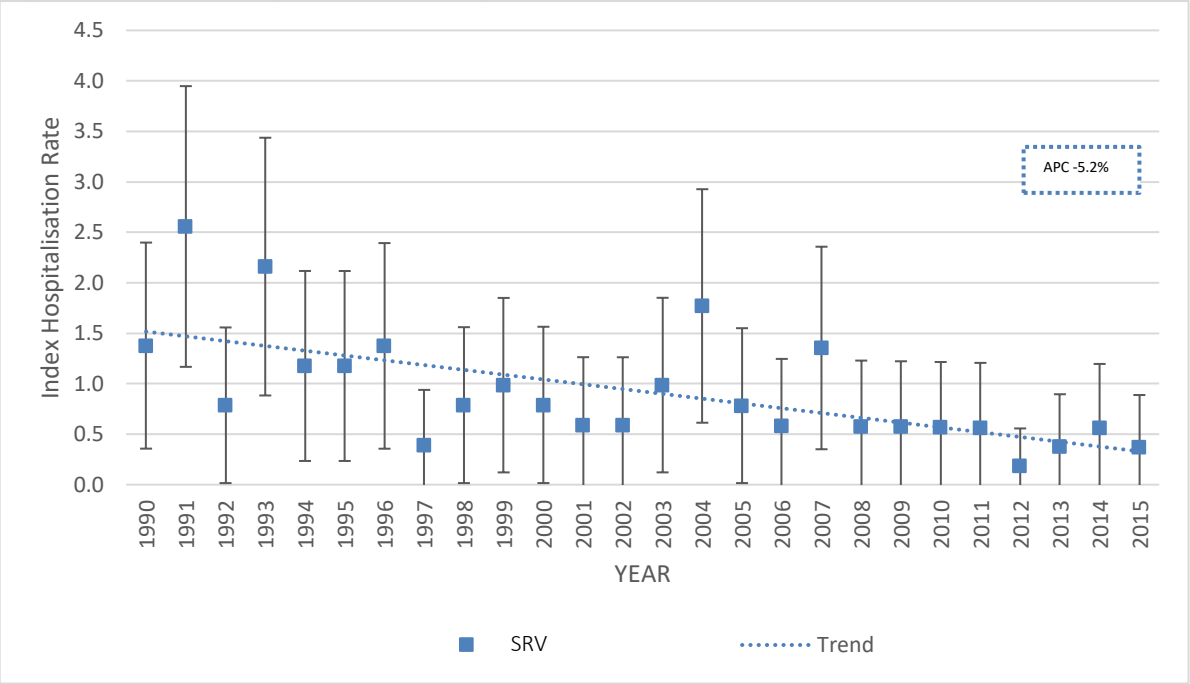
There was a 4.2% (95% CI 1.3 – 7.3%, $p<0.05$) annual increase in the index hospitalisation rate with TGA switch.

5.3.2.9 Systemic Right Ventricle (SRV)

A total of 123 patients with SRV had an index hospitalisation within the 25-year period. This represents 0.7% of the total number of patients with CHD lesions admitted to hospital. The number of index hospitalisations per year ranged from 1 – 13.

The index hospitalisation rate per 1 000 000 of the population with a diagnosis of SRV admitted in 1990 is 1.4 compared to 0.4 in 2015. The index hospitalisation rate per year with a diagnosis of TGA Switch indexed to 1 000 000 of the population is shown in Table 10, Appendix 1 and is displayed in Figure 5-10.

Figure 5-10 Index hospitalisation rate per annum for individuals with SRV



Index hospitalisation rate per annum for individuals with SRV expressed as rate per 1 000 000 general population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

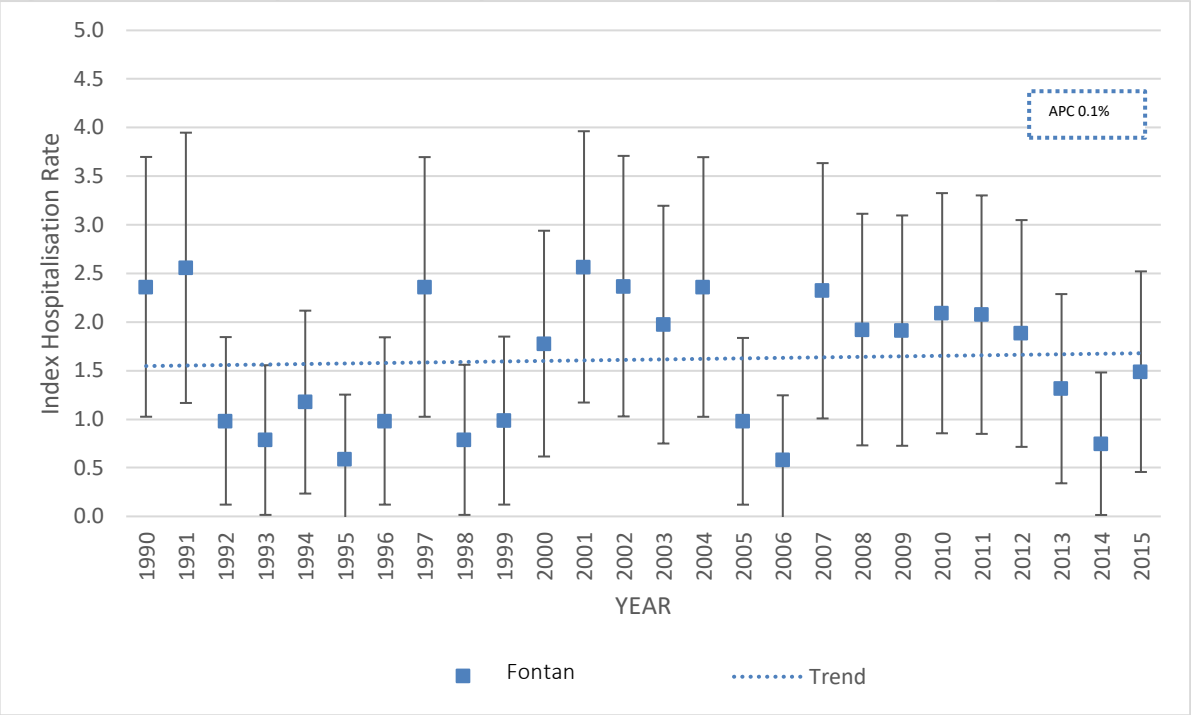
There was a 5.2% (95% CI -7.4 - -2.8%, p<0.05) annual decrease in the index hospitalisation rate with SRV.

5.3.2.10 Fontan Repair (Fontan)

216 patients with Fontan had an index hospitalisation within the 25-year period. This represents 1.2% of the total number of patients with CHD lesions admitted to hospital. The number of index hospitalisations per year ranged from 3 – 13.

The index hospitalisation rate per 1 000 000 of the population with a diagnosis of Fontan admitted in 1990 is 2.4 compared with 1.5 in 2015. The index hospitalisation rate per year with a diagnosis of Fontan indexed to 1 000 000 of the population is shown in Table 11, Appendix 1 and is displayed in Figure 5-11.

Figure 5-11 Index hospitalisation rate per annum for individuals with Fontan repair



Index hospitalisation rate per annum for individuals with Fontan repair expressed as rate per 1 000 000 general population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

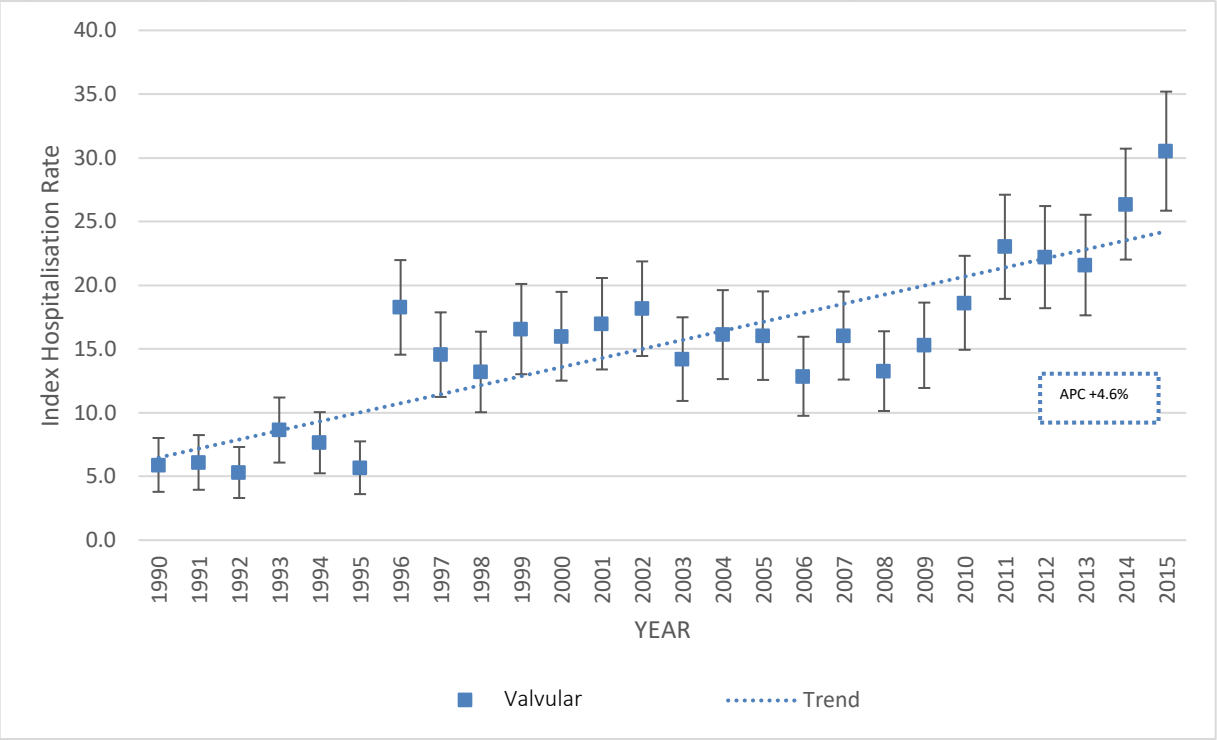
There was no change in the annual index hospitalisation rate of patients with Fontan, the APC was 0.1% (95% CI -2.3 - 2.2%, p=0.9).

5.3.2.11 Congenital Valvular Lesions, not otherwise classified (Valvular)

2 069 patients with congenital valvular lesions had an index hospitalisation within the 25-year period. This represents 11.5% of the total number of patients with CHD lesions hospitalised. The number of index hospitalisations per year ranged from 27 – 164.

The index hospitalisation rate per 1 000 000 of the population with a diagnosis of congenital valvular lesions admitted in 1990 is 5.9 compared with 30.5 in 2015. The index hospitalisation rate per year with a diagnosis of valvular lesions indexed to 1 000 000 of the population is shown in Table 12, Appendix 1 and is displayed in Figure 5-12.

Figure 5-12 Hospitalisation rate per annum for individuals with congenital valvular lesions



Index hospitalisation rate per annum for individuals with congenital valvular lesions expressed as rate per 1 000 000 general population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

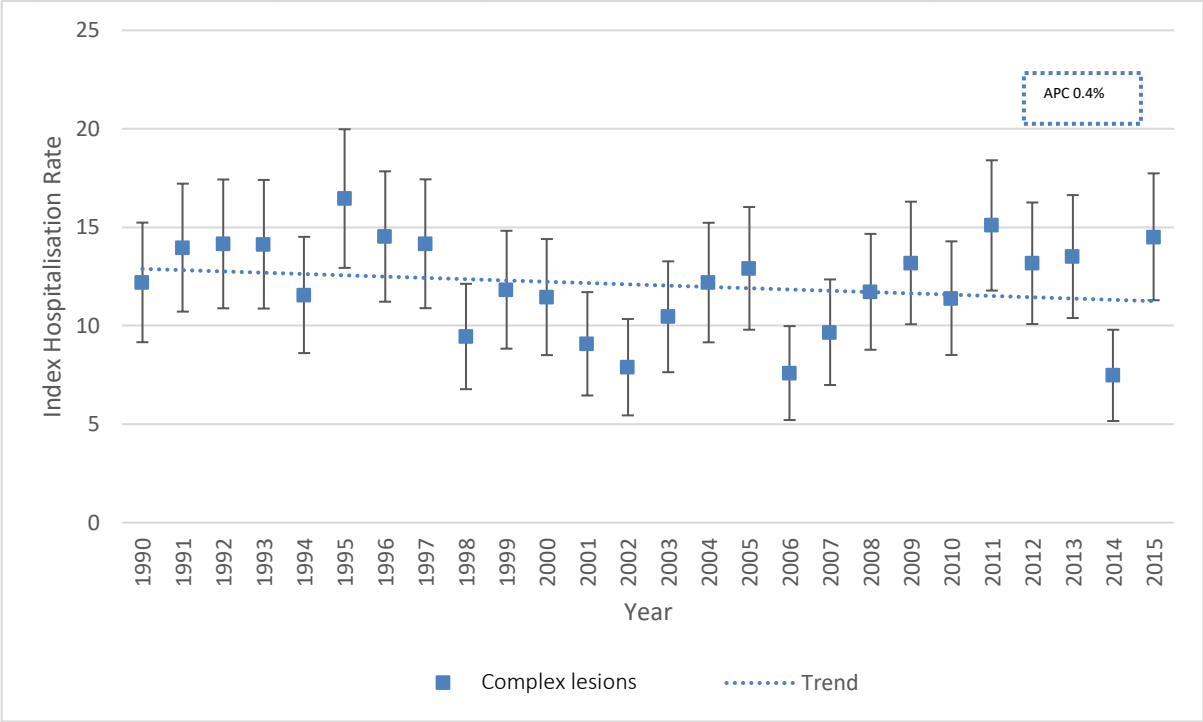
There was a 4.6% (95% CI 3.2 – 6.0%, p<0.05) annual increase in the index hospitalisation rate with congenital valvular lesions.

5.3.2.12 Complex Lesions, not otherwise classified

1 618 patients with complex lesions had an index hospitalisation within the 25-year period. This represents 9.0% of the total number of patients with CHD lesions hospitalised. The number of index hospitalisations per year ranged from 39 – 81.

The index hospitalisation rate per 1 000 000 of the population with a diagnosis of complex lesions admitted in 1990 is 12.2 compared to 14.5 in 2015. The hospitalisation rate per year with a diagnosis of complex lesions indexed to 1 000 000 of the population is shown in Table 13, Appendix 1 and is displayed in Figure 5-13.

Figure 5-13 Index hospitalisation rate per annum for individuals with complex lesions



Index hospitalisation rate per annum for individuals with complex CHD lesions (not otherwise classified) expressed as rate per 1 000 000 general population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

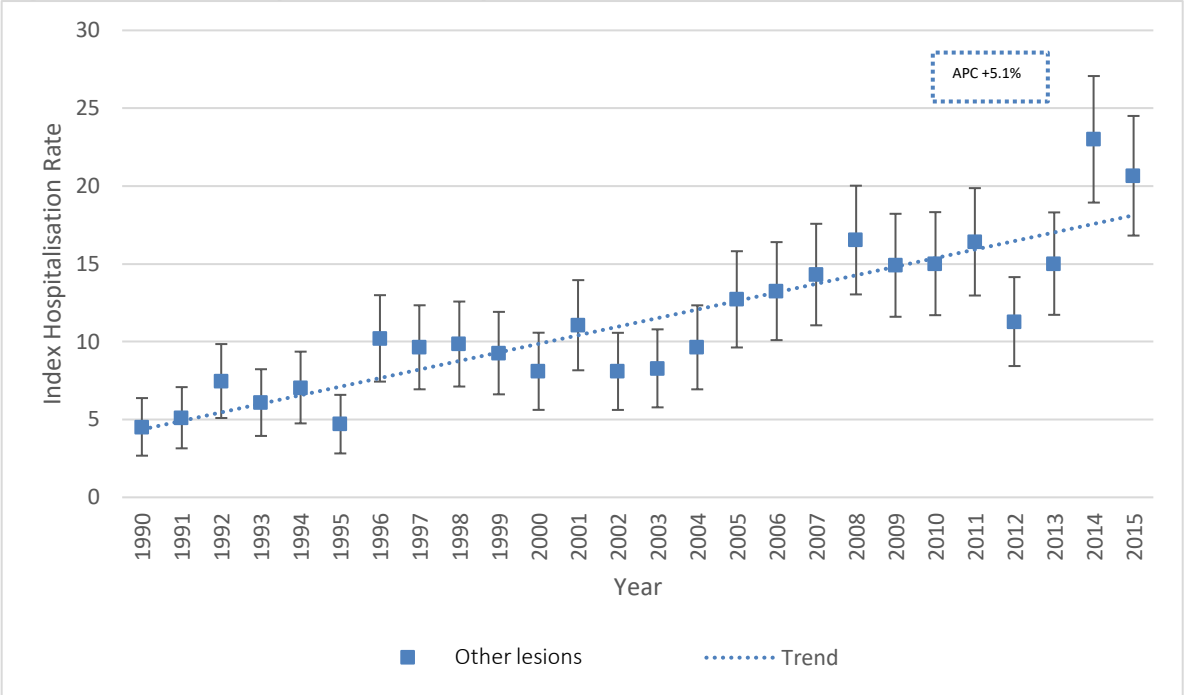
There was no change in the annual index hospitalisation rate of patients with complex lesions, the APC was 0.4% (95% CI -1.5 – 0.6%, p=0.4).

5.3.2.13 Other Congenital Lesions, not otherwise classified

1 516 patients with other lesions had an index hospitalisation within the 25-year period. This represents 8.4% of the total number of patients with CHD lesions hospitalised. The number of index hospitalisations per year ranged from 23 - 123.

The index hospitalisation rate per 1 000 000 of the population with a diagnosis of other lesions admitted in 1990 is 4.5 compared to 20.7 in 2015. The index hospitalisation rate per year with a diagnosis of other lesions indexed to 1 000 000 of the population is shown in Table 14, Appendix 1 and is displayed in Figure 5-14.

Figure 5-14 Index hospitalisation rate per annum for individuals with other lesions



Index hospitalisation rate per annum for individuals with other CHD lesions (not elsewhere classified) expressed as rate per 1 000 000 general population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

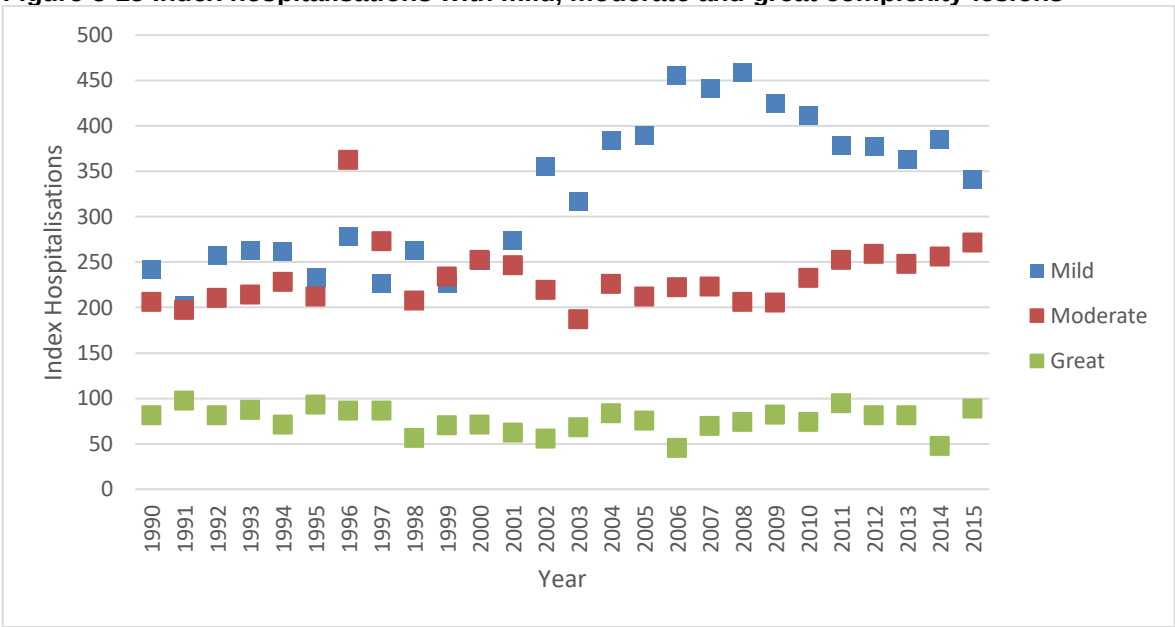
There was a 5.1% (95% CI 1.4 – 2.8%, $p<0.05$) annual increase in the index hospitalisation rate with other lesions.

5.3.3 Lesion Complexity

As outlined in the introduction of this chapter, CHD lesions can be grouped together, depending on the physiological severity of the underlying congenital lesion into groups of mild, moderate and great complexity.

Figure 5-15 shows the temporal distribution of index hospitalisation in each complexity grouping.

Figure 5-15 Index hospitalisations with mild, moderate and great complexity lesions



Index hospitalisations per annum for patients with mild, moderate and great complexity CHD lesions. The blue squares represent CHD lesions of mild complexity. The red squares represent CHD lesions of moderate complexity. Green squares represent CHD lesions of great complexity.

5.3.3.1 Lesions of Mild Complexity

Diagnoses included in lesions with mild complexity include

a) Atrial septal defect

b) Ventricular Septal Defect

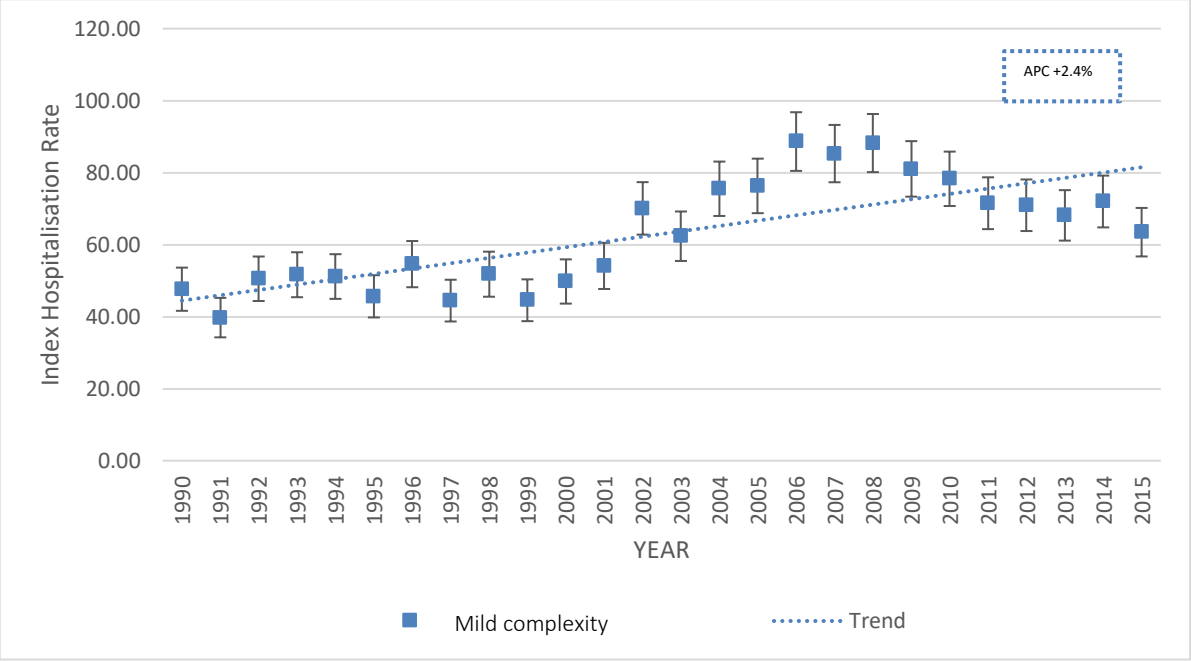
c) Patent Ductus Arteriosus

8 458 patients with CHD lesions of mild complexity had an index hospitalisation in the 25-year period. This represents 47.1% of all patients with CHD

hospitalisations. The number of index hospitalisations per annum ranged from 202 – 459.

The index hospitalisation rate per 1 000 000 of the population with a CHD lesion of mild complexity admitted in 1990 is 47.6 and 63.5 in 2015. The index hospitalisation rate per year with a diagnosis of lesions of mild complexity lesions indexed to 1 000 000 of the population is shown in Table 15, Appendix 1 and is displayed in Figure 5-16.

Figure 5-16 Index hospitalisation rate per year with a CHD lesion of mild complexity



Index hospitalisation rate per annum for individuals with CHD lesions of mild complexity expressed as rate per 1 000 000 general population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

There was a 2.4% (95% CI 1.5 – 3.3%, $p<0.05$) annual increase in the index hospitalisation rate of those lesions of mild complexity.

5.3.3.2 Lesions of Moderate Complexity

Diagnoses in CHD lesions of moderate complexity included:

a) Aortic anomalies

b) Ebstein's Anomaly

c) Atrioventricular septal defect

d) Tetralogy of Fallot

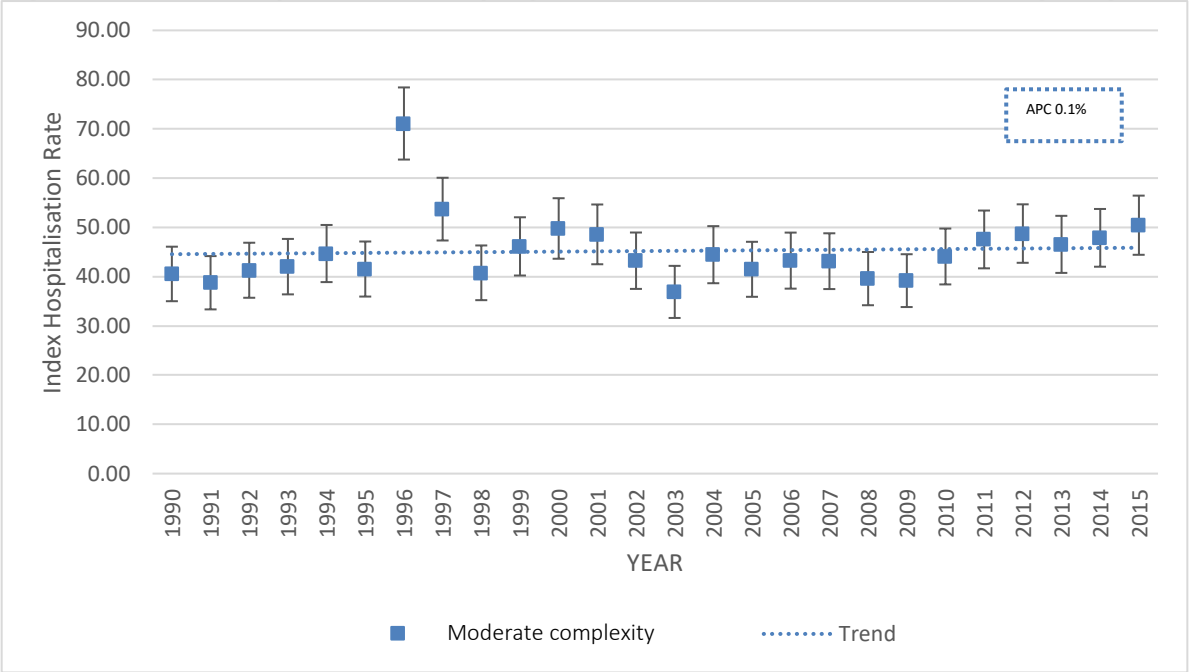
e) TGA with arterial switch

f) Congenital valvular heart disease, not otherwise specified

6 059 patients with CHD lesions of moderate complexity had an index hospitalisation within the study period. This represents 33.7% of all patients with CHD hospitalisations. The number of index hospitalisations per annum ranged from 187 – 362.

The index hospitalisation rate per 1 000 000 of the population with a CHD lesion of moderate complexity hospitalised was 40.5 in 1990 and 50.4 in 2015. The hospitalisation rate per year with a diagnosis of a moderate complexity lesions indexed to 1 000 000 of the population is shown in Table 16, Appendix 1 and is displayed in Figure 5-17.

Figure 5-17 Index hospitalisation rate per year with a CHD lesion of moderate complexity



Index hospitalisation rate per annum for individuals with CHD lesions of moderate complexity expressed as rate per 1 000 000 general population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

There was no change in the annual index hospitalisation rate of moderate lesion complexity, the APC was 0.1% (95% CI -0.7 – 0.9%, p=0.9).

5.3.3.3 Lesions of Great Complexity

Diagnoses included in CHD lesions of great complexity include:

a) Systemic right ventricle

b) Fontan

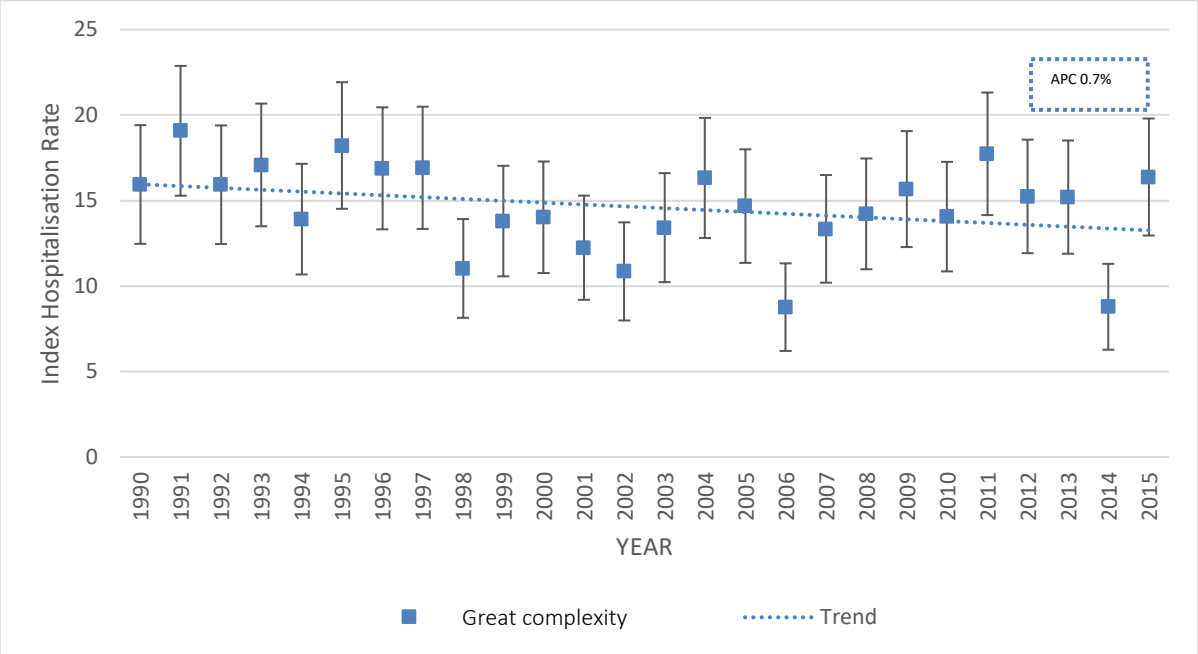
c) Complex lesions, not otherwise specified

1 957 patients with CHD lesions of great complexity had an index hospitalisation within the study period. This represents 10.9% of all patients with CHD hospitalisations. The number of index hospitalisations per annum ranged from 45 - 97.

The index hospitalisation rate (per 1 000 000 of the general population) of individuals with a CHD lesion of great complexity admitted was 15.9 in 1990 and

16.4 in 2015. The index hospitalisation rate per annum with a diagnosis of complex lesions indexed to 1 000 000 of the general population is shown in Table 17, Appendix 1 and is displayed in Figure 5-18.

Figure 5-18 Index hospitalisation rate per year with a CHD lesion of great complexity



Index hospitalisation rate per annum for individuals with CHD lesions of great complexity expressed as rate per 1 000 000 general population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

There was no change in the annual index hospitalisation rate of great lesion complexity, the APC was 0.7% (95% CI -1.6 – 0.3%, p=0.2).

5.3.4 APC Summary

Table 5-2 contains a summary of the APC for each CHD lesion and complexity grouping. For those lesions were there were multiple joinpoints in the APC temporal trend one should refer to the corresponding figure for that cohort. A significant increase ($p<0.05$) in the APC is prefixed by a "+" and a significant decrease ($p<0.05$) in the APC is prefixed by a "-".

Table 5-2 Summary table of the APC for each CHD lesion and complexity group

	Index Hospitalisations (n)	Annual Percentage Change
Lesions		
All	17 990	+1.5%
ASD	4 184	Multiple joinpoints
PDA	1 707	No change
VSD	2 567	No change
AVSD	866	-1.8%
Aortic	2 003	Multiple joinpoints
Ebstein's	120	No change
ToF	781	-1.4%
TGA	220	+4.2%
SRV	123	-5.2%
Fontan	216	No change
Valvular	2 069	+4.6%
Complex	1 618	No change
Other	1 516	+5.1%
Complexity		
Mild	8 458	+2.4%
Moderate	6059	No change
Great	1 957	No change

+ significant increase in APC, $p<0.05$; - significant decrease in APC, $p<0.05$

5.4 Discussion

There was a total of 17 990 index hospitalisation of patients with CHD in Scotland during the study period. In my study of the index hospitalisation rates of the CHD population in Scotland, I found a crude prevalence of 3.3 per 1 000 of the Scottish population (based on the 2015 Scottish population). This is in line with published CHD prevalence estimates of 5.78 per 1 000 in the general population[24]. This represents a substantial study population and is the largest such study of both adults and children with CHD in Scotland and one of the largest in the world for index hospitalisations. Only one other study[62] in the literature review reported more index hospitalisations (n=61 051). This was a population study within Canada which has a higher baseline population and inherently a larger number of patients with CHD.

5.4.1 Baseline Characteristics

There was no difference in index hospitalisation between women and men (50.1% women, p=0.79). This appears to be in keeping with the published literature showing no clear difference in either sex (4 articles in the literature review reporting higher hospitalisation rates in women, 5 reporting higher rates in men), when all CHD lesions are considered. However, index hospitalisations among certain lesions appeared to be higher among either sex. Women had more index hospitalisations with diagnoses of ASD (57.3%, p<0.05), PDA (56.3%, p<0.05), Ebstein's (60.8%, p<0.05) and AVSD (57.0%, p<0.05), whereas men had more index hospitalisations with ToF (57.5%, p<0.05), TGA arterial switch (68.6%, p<0.05), Fontan (64.8%, p<0.05) congenital valvular defects (57.6%, p<0.05), Aortic lesions (54.5%, p<0.05) and SRV (59.3, p<0.05). This is in keeping with the lesion sex differences outlined within the literature review.[65,72–74]

Over the study period there was an increase in the index hospitalisation rate of 1.5% (95% CI 1.0 - 1.9%, p<0.05) per year. This finding is in keeping with the 1.1% annual increase in hospitalisation rate reported by Islam et al.[62] During the same study period there was an increase in the number of hospitalisations and there was an increase of 1.1% (95% CI 0.8 – 1.5%, p<0.05) in the annual hospitalisation rate in Scotland for the general population.[90] Although there is an increasing rate among CHD index hospitalisations and all hospitalisations

within Scotland, the rate of increase within the CHD population appears to be increasing at a higher rate. While this is not of statistical significance, one must consider that it is index hospitalisations that is reported in my analysis and not all hospitalisations which is reported for Scotland by NSD. One would imagine that if all CHD hospitalisations were to be examined then the hospitalisation rate would be significantly higher than that of the general population.

Mild complexity CHD index hospitalisations (51.3%) made up the largest group with regards to lesion severity groupings, followed by moderate complexity (36.8%) and lastly by lesions of great complexity (11.9%). Although prior studies[61,62] within the literature review would agree that lesions of mild complexity make up the greatest proportional share of hospitalisations, their representative share was much larger for mild lesions (75%)[61] compared to that which I have demonstrated. One possible explanation for this includes their use of all hospitalisations and not only index events and inclusion of valvular lesions with no haemodynamic significance in the mild complexity group.[62] Due to anonymised data with which this thesis was constructed, I was not able to identify patients or quantify valvular function and therefore included all valvular lesions along with lesions of moderate complexity which offers another possible explanation for the difference between my findings and those published by others.[61,62]

5.4.2 Lesions and Complexity

The most significant reason to explain any increase in CHD hospitalisation is due to the advances over the last 70 years in the care of neo-natal and paediatric patients born with even the most complex forms of CHD. As a result, more than 30% are diagnosed prenatally and greater than 90% of these individuals are now expected to survive to adulthood.[91] This significant achievement has been due to developments in diagnostic technologies including transthoracic and foetal echocardiography, catheter based interventions as well as therapeutic and surgical technique innovations.[8]

Increasing survival of patients with CHD from birth through to older age, means that the prevalence of patients with CHD is increasing.[24] Despite the advances, many patients with CHD who undergo invasive procedures to improve systemic

and pulmonary blood supply as well as correct haemodynamic defects will not have a durable lifelong repair. As a result of a failing repair, or directly due to original cardiac anatomy, these patients have been shown to be more likely to require hospitalisation when compared to those without CHD. Reasons for hospitalisation are countless, although common cardiac morbidity among patients with CHD include arrhythmia, heart failure and infective endocarditis.

With increased survival comes increased exposure to cardiovascular risk factors. Agarwal et al.[92] demonstrated an increase in the exposure to hypertension, diabetes mellitus, smoking, obesity and chronic kidney disease among a CHD population presenting to the emergency department. This increased exposure to cardiac risk factors will increase the likelihood of acquired heart disease such as coronary artery disease and ischaemia in the congenital population and will also contribute to cardiac hospitalisations. Non-cardiac hospitalisation would also be expected to increase. Examples are numerous and include an increasing number of women with CHD living to reproductive age and subsequent increase in the rate of pregnancies in those with CHD has been previously demonstrated and it is predicted that the increase in pregnancy rate would continue to rise.[93] Also, increased hospitalisation with stroke and cerebrovascular disease in young adults with CHD compared to the general population has previously been reported.[94]

Patients with ASDs and VSDs were among the most frequent types of CHD hospitalised in this study. These lesions made up 37.6% (n=6 751) of all index CHD hospitalisations. This is similar to findings reported by Liu et al.[95] in their meta-analysis of worldwide prevalence of CHD lesions, they concluded that the two most prevalent CHD lesions within CHD population were ASD and VSD. I found that ASDs represented 23.3% of all index CHD hospitalisations which is similar to that reported by Verheugt[96] and Koh et al.[78] who reported ASD representing 18% and 24% of their total CHD hospitalisations respectively. The increase in index hospitalisation of lesions of minor complexity is in some part due to the increase in quality of diagnostic imaging techniques including echocardiography, as well as pre-natal echocardiography imaging allowing more patients with lesions of mild complexity to be identified. The 573%[97] 10-year increase in the use of cross-sectional imaging modalities, including cardiac MRI

and CT in the UK, will also have a role to play in the increased diagnosis of CHD lesions of mild severity, some of which will be incidental findings.

The index hospitalisation rate trend for ASDs is interesting. The ICD coding for this specific diagnosis includes both that of ASD and PFO; both grouped within the same code and indistinguishable without access to individual case records or cardiac imaging. The presence of a persistent or patent foramen ovale is not thought to be in itself a congenital defect conferring a disease process, as it has been found to be present in up to 24% of adults at post-mortem assessment.[98] The index hospitalisation rates in my analysis show a gradual increase over time which likely reflects an increased quality and use of echocardiography, but also to cross sectional imaging modalities such as cardiac MRI and CT. However, there is a sharp increase in the index hospitalisation rates between 2002 and 2008, before reverting to the gradual increase as described above. An explanation for this could be due to the increase in rate of percutaneous closure in PFOs in patients with migraine and cryptogenic ischaemic stroke during the early 2000's. Subsequently, randomised controlled trials in recurrent migraine[99] concluded that there was no overall benefit in migraine prevention. As a direct result, the procedure was not recommended in the NICE guidance for migraine management in 2010.[100] Similarly, during this time there has been emergent evidence to indicate that there was no overall benefit of medical therapy compared to device closure of PFO on recurrence of cryptogenic stroke.[101] This sharp rise of PFO intervention during the early 2000s before levelling off was also reported by Farrooqi et al. in their review of the National Institute for Cardiovascular Outcomes Research (NICOR) database[102] on the closure of PFOs nationally within the United Kingdom. Since my data was collected there has been studies demonstrating that device closure of PFO in patients with cryptogenic stroke is superior to medical treatment alone.[103] Considering this evidence, clinicians are more likely to investigate for the presence of a PFO in suspected cryptogenic stroke and one would therefore expect to now see an increase in the hospitalisation rate of patients with PFO. Overall prevalence of ASDs in adults in my study is high (n= 3 090 (36.4% of index adult hospitalisations), similar hospitalisation frequency has been demonstrated elsewhere.[77]

There was a decreasing rate of index hospitalisations in patients with AVSD from 6.1 per 1 000 000 of the population in 1990 to 5.0 in 2015 resulting in a decrease in the annual index hospitalisation rate of 1.8% ($p<0.05$). One possible explanation for this trend is that AVSD is associated with chromosomal defects, in particular trisomy 21.[104] It is estimated that 90% of parents who have a prenatal foetal screening diagnosis of trisomy 21 will elect to have the pregnancy terminated.[105] This will result in a reduction in the birth incidence of AVSD and subsequently an observed reduction in index hospitalisation rates of this CHD lesion.

There were no observed index hospitalisations for adults with TGA arterial switch in this study. This is what I would expect given the natural history of the underlying CHD lesions requiring surgical intervention in the neonatal period and my grouping requirement to have both ICD and OPCS code required to accurately identify this lesion. Also notable is that there are no TGA arterial switch hospitalisations observed until 1993. All congenital cardiac surgery in Scotland is carried out in a single centre. From personal discussion with experienced congenital cardiac surgeons who worked during the time, they have reported that it was not until 1993 that these procedures were first carried out within Scotland and therefore my findings would mirror that of real-life experience.

48.7% of those patients with an index hospitalisation had diagnoses of moderate or great complexity. There was no increase in the overall rate of hospitalisations observed for those lesions of moderate complexity. They represented a substantial portion (36.8%) of the total index hospitalisations. Those lesions of great complexity (11.9% index hospitalisations) also a stable rate of index hospitalisation over the period of the study. A similar finding was reported by Islam et al.[62] who also reported no overall change in the hospitalisation rates of moderate complexity, but observed an overall increase in the annual hospitalisation rate of 2.5% for lesions of mild, moderate and great complexity. This not only has implications in providing care in an inpatient setting, as identified by the frequency of hospitalisations, but also impacts the outpatient care requirement for this dynamic and complex group of patients. Patients with moderate and great complexity lesions have care needs that require them to be

reviewed lifelong in specialist CHD centres by dedicated CHD clinicians and teams with interval assessment and investigation.

The year 1996 appears to be an outlier with respect to the overall index hospitalisation rate. A significantly higher rate that year is observed compared to the surrounding years. This is also evident in aortic lesions and CHD lesions of moderate complexity. A possible explanation for this is that 1996 was the year that Scotland introduced ICD-10 (from ICD-09) for clinical coding of diagnosis and comorbidity.[106] The introduction of an updated and more complex coding directory for clinical coders could account for this finding. Alternatively, this may be a true reflection of the number of patients with an index hospitalisation that year with the diagnoses discussed above. If the remaining index hospitalisations for aortic anomalies after the change in ICD coding is viewed, there is almost a flat trend line which may represent the true underling numbers of patients with aortic CHD lesions.

5.5 Conclusion

This study has demonstrated that the incidence of index hospitalisation and hospitalisation rates for patients with CHD in Scotland is increasing by an annual rate of 1.5%. This is driven by a significant increase in the rates of hospitalisations of mild complexity lesions, although the rates of moderate complexity index hospitalisation were stable over the observed study period. The findings of this study are in keeping with those reported among the literature.

Although the overall number of index hospitalisations appears similar from the baseline characteristics in both sexes, there are distinct trends within hospitalisation that may vary between the sexes. In the next chapter I will explore the sex specific rates of hospitalisation for CHD in Scotland.

6 Sex

6.1 Introduction

In this Chapter, I describe the number of index CHD hospitalisations based on sex of the patients presenting to Scottish hospitals between the years 1990 and 2015. Firstly, I look at the differences in overall index hospitalisation rates between the sexes. Secondly, I look at the sex-specific differences in index hospitalisation rates between children and adults. Lastly, I compare the index hospitalisation rates of both sexes with respect to underling CHD lesion severity.

6.2 Methods

The methods used within this chapter are as outlined in Chapter 4 Methods. The age definition of children will be defined as those <16 years and adults will be defined as those individuals ≥16. Girls will refer to those female children under the age of 16, and boys will refer to those male children under the age of 16. Women will refer to adult females and men will refer to adult males. Where the term male is used, this refers to both men and boys. Where the term female is used, this refers to both women and girls.

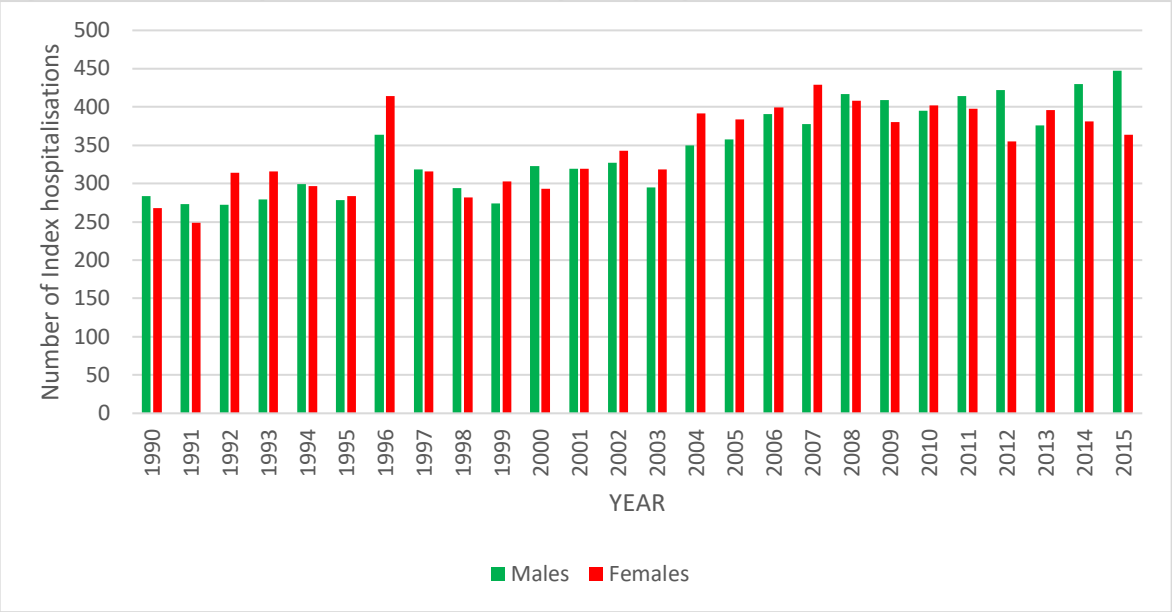
6.3 Results

6.3.1 Baseline Characteristics

As described in Chapter 5, a total of 17 990 patients had an index hospitalisation with a diagnosis of CHD within the study period. Of the 17 990 hospitalisations, 8 986 (49.9%) were male and 9 004 (51.1%) were female.

The number of annual index hospitalisation stratified by sex is shown in the Figure 6-1.

Figure 6-1 Index hospitalisations stratified by sex per year with CHD



Index hospitalisations per annum for all individuals with CHD stratified by sex per year. The green bars represent male index hospitalisations. The red bars represent female index hospitalisations.

A table summarising the baseline characteristics of all individuals as well as those for both sexes is found in Table 6-1.

Table 6-1 Summary of baseline characteristics for both sexes

	All	Male	Female	p-value
Hospitalisations, n (%)				
All	17 990 (100)	8 986 (49.9)	9 004 (50.1)	0.79
Adults	8 482 (47.1)	4 029 (44.8)	4 453 (49.5)	<0.05
Children	9 508 (52.9)	4 951 (55.2)	4 551 (50.5)	<0.05
Median Age, years	25	23	27	
SIMD Quintile, n (%)				
1 (most deprived)	4 849 (27.2)	2 307 (25.7)	2 542 (28.2)]	<0.05
2	3 827 (21.4)	1 900 (21.1)	1 927 (21.4)	<0.05
3	3 339 (18.7)	1 690 (18.8)	1 649 (18.3)	<0.05
4	3 019 (16.9)	1 565 (17.4)	1 454 (16.1)	<0.05
5 (least deprived)	2 818 (15.8)	1 445 (16.1)	1 373 (15.2)	<0.05
Lesion, n (%)				
ASD	4 184 (23.2)	1 787 (19.9)	2 397 (26.6)	<0.05
PDA	1 707 (9.5)	746 (8.3)	961 (10.7)	<0.05
VSD	2 567 (14.3)	1 312 (14.6)	1 255 (13.9)	0.27
AVSD	866 (4.8)	372 (4.1)	494 (5.5)	<0.05
Aortic	2 003 (11.1)	1 092 (12.2)	911 (10.1)	<0.05
Ebstein's	120 (0.70	47 (0.5)	73 (0.8)	<0.05
ToF	781 (4.3)	449 (5.0)	332 (3.7)	<0.05
TGA	220 (1.2)	151 (1.7)	69 (0.8)	<0.05
SRV	123 (0.7)	73 (0.8)	50 (0.6)	<0.05
Fontan	216 (1.2)	140 (1.6)	76 (0.9)	<0.05
Valvular	2 069 (11.5)	1 192 (13.3)	877 (9.7)	<0.05
Complex	1 618 (9.0)	831 (51.4)	787 (48.6)	0.26
Other	1 516 (8.4)	794 (52.4)	722 (47.6)	0.06
Lesion Complexity, n (%)				
Mild	8 458 (47.0)	3 845 (46.9)	4 613 (51.2)	<0.05
Moderate	6 059 (33.7)	3 376 (41.2)	2 683 (29.8)	<0.05
Great	1 957 (10.9)	971 (11.9)	986 (11.9)	0.72

Overall, there was no difference in the number of index hospitalisations between males (n=8 986, 49.9%) and females (n=9 004, 50.1%), p=0.79. Girls (n 4 551, 47.9%) had less index hospitalisations than boys (n=4 951, 52.1%), p<0.05. Women (n=4 453, 52.3%) had more index hospitalisations than men (n=4 029, 47.7%), p<0.05.

Measures of deprivation (SIMD) were available for 17 852 patients. There were significantly more index hospitalisations observed for both males (n= 2307, p<0.05) and females (n= 2452, p<0.05) in the most deprived areas (SIMD1). There were significantly more females (n=2 542) with index hospitalisations in the most deprived (SIMD1) quintiles compared to males (n=2 307, p<0.05). There was no difference between the number of females (n=1 373) and males (n=1 445, p=0.17) with index hospitalisations in the least deprived quintile (SIMD5).

Index hospitalisations involving shunt lesions including ASD, PDA and AVSD occurred more commonly in females (p<0.05). Whereas, Aortic, ToF, TGA, Fontan and valvular lesions occurred more often in males than females (p<0.05). Females (n=4 613) had more index hospitalisations than males (n= 3 845, p<0.05) in lesions of mild complexity. Females (n=2 683) had less index hospitalisations than males (n=3 376, p<0.05) in lesions of moderate complexity. There was no difference in between female (n=986) and male (n=971, p=0.72) index hospitalisations lesions of great complexity.

6.3.2 All Index Hospitalisations

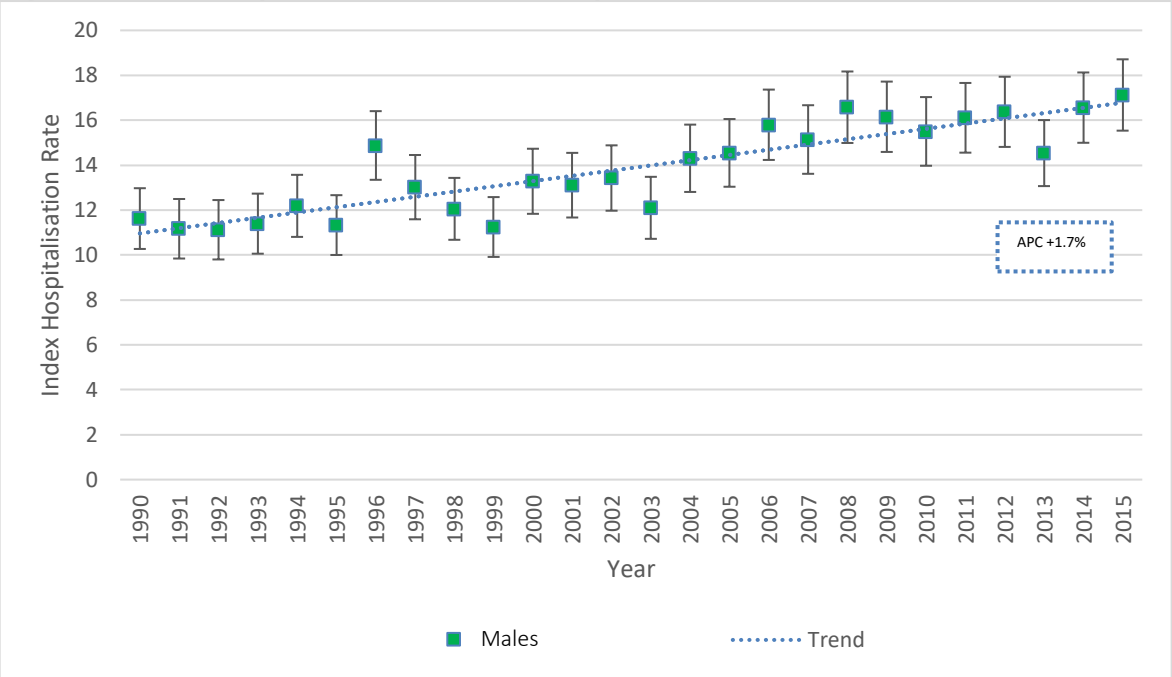
6.3.2.1 Index Hospitalisation in Males and Females

8 986 males with CHD had an index hospitalisation within the study period. The index hospitalisation rate (per 100 000 of the population of Scottish males), rose from 11.6 (95% CI 10.3–13.0) in 1990 to 17.1(95% CI 15.5–18.7) in 2015. Index hospitalisation rates ranged from 11.1 to 17 per 100 000. The index hospitalisation rates each year per 100 000 of the Scottish male population is shown in Table 1, Appendix B and is displayed in Figure 6-2.

9 004 females with CHD had an index hospitalisation within the study period. The index hospitalisation rate per 100 000 of the population of Scottish females,

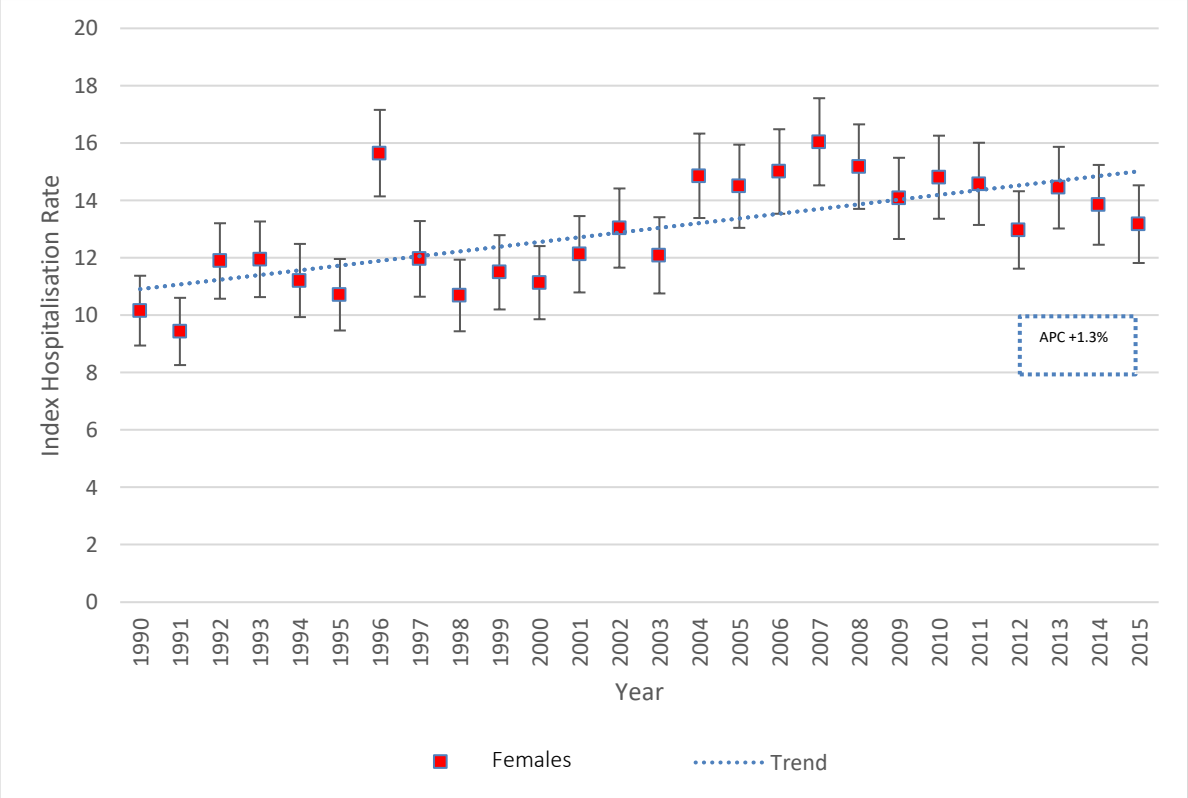
rose from 10.2 (95%CI 8.9-11.4) in 1990 compared with 13.2 (95%CI 11.8-14.5) in the 2015. Index hospitalisations ranged from 9.4 to 16.1 per 100 000. The index hospitalisation rate for females per 100 000 of the Scottish female population is demonstrated in the Table 2, Appendix B and is displayed in Figure 6-3.

Figure 6-2 Index hospitalisation rates of males per annum with CHD



Index hospitalisation rate per annum for male individuals with CHD expressed as rate per 100 000 of the male population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

Figure 6-3 Index hospitalisation rates of females per annum with CHD



Index hospitalisation rate per annum for female individuals with CHD expressed as rate per 100 000 of the female population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

There was an annual increase in the index hospitalisation rates in both sexes. In males there was a 1.7% (95% CI 1.3 – 2.1%, p<0.05) annual increase and in females there was a 1.3% (95% CI 0.6 – 1.9%, p<0.05) annual increase in the index hospitalisation rate of females over the study period.

6.3.3 Sex and Age

6.3.3.1 Boys and Girls

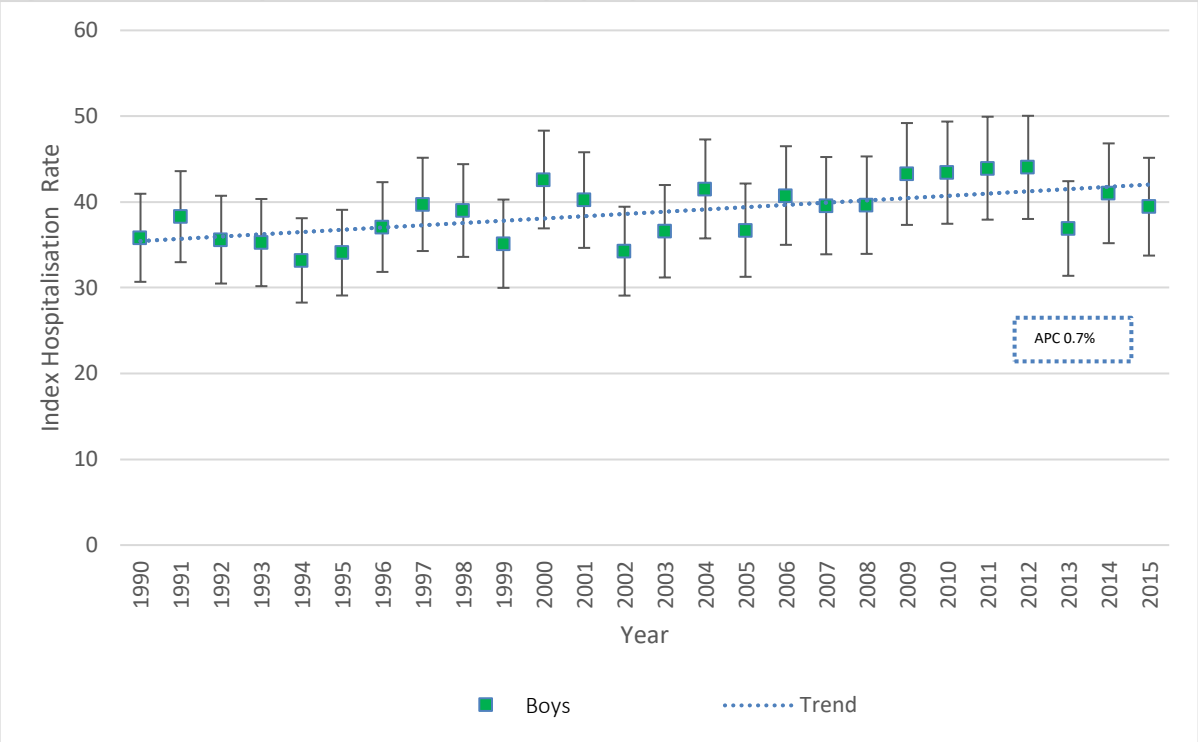
A total number of 8 986 males with CHD had an index hospitalisation within the observed years 1990 – 2015. Of this, 4 957 (55%) were boys. The index hospitalisation rate for boys, standardised against the Scottish male population under the age of 16, increased from 35.8 (95%CI 25.6-46.1) in 1990 to 39.5 (95%CI 30.3-48.6) in 2015. The index hospitalisation rate ranged from 33.2 to 44.0 per 100 000.

The index hospitalisation rate of boys with a diagnosis of CHD each year, per 100 000 of the Scottish male population under the age of 16, is shown in Table 3, Appendix B and is displayed in Figure 6-4.

9 004 females with CHD had an index hospitalisation within the study period. Of this, 4 551 (50.5%) were girls. When standardised for the Scottish population of females under the age of 16 per year, index hospitalisation rates varied from 34.7 (95% CI 29.6-39.9) in 1990 compared with 36.3 (95% CI 30.7-41.9) in 2015. The index hospitalisation rate ranged from 31.0 to 46.0 per 100 000.

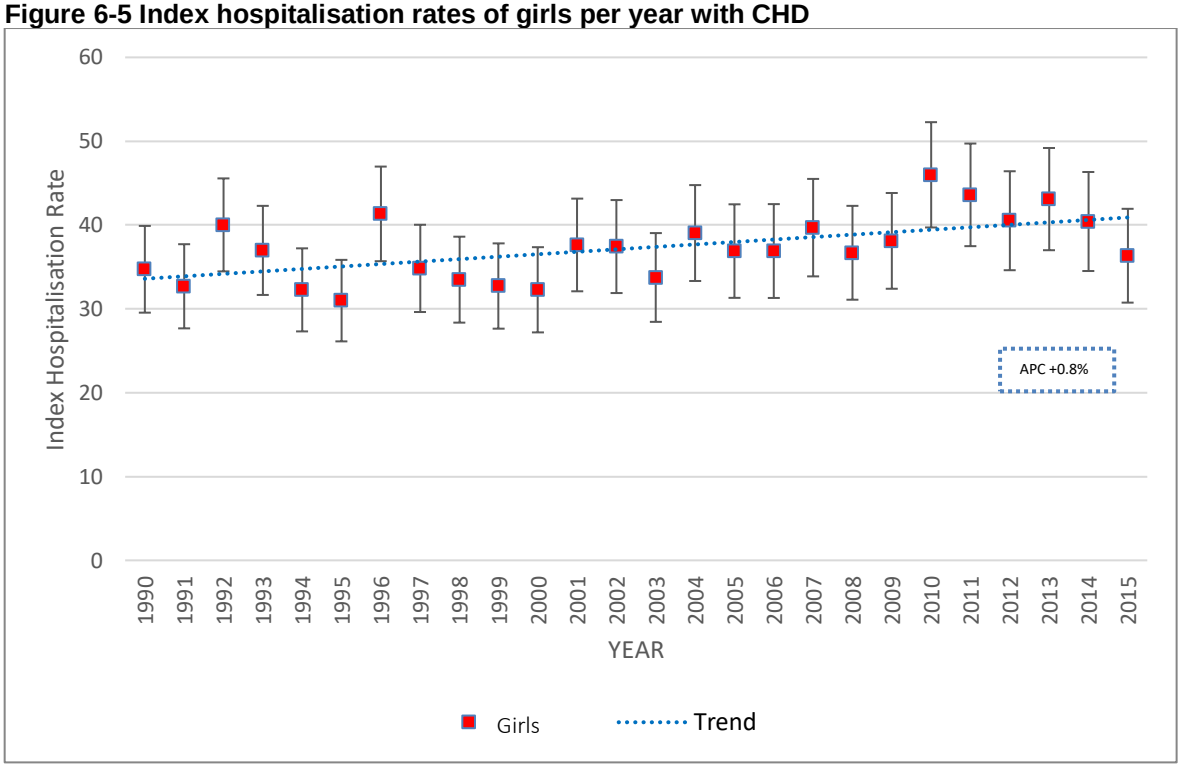
The index hospitalisation rate of girls with a diagnosis of CHD each year, per 100 000 of the Scottish female population under the age of 16, is shown in the Table 4, Appendix B and is displayed in Figure 6-5.

Figure 6-4 Index hospitalisation rates of boys per year with CHD



Index hospitalisation rate per annum for boys with CHD expressed as rate per 100 000 of the male population aged <16 years old. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

Figure 6-5 Index hospitalisation rates of girls per year with CHD



Index hospitalisation rate per annum for girls with CHD expressed as rate per 100 000 of the female population aged <16 years old. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

There was no change in the annual index hospitalisation rate for boys, the APC was 0.7% (95% CI -0.3 – 1.1%, p=0.9). There was a 0.8% (95% CI 0.3 – 1.2%, p<0.05) increase in the annual index hospitalisation rate of girls.

6.3.3.2 Men and Women

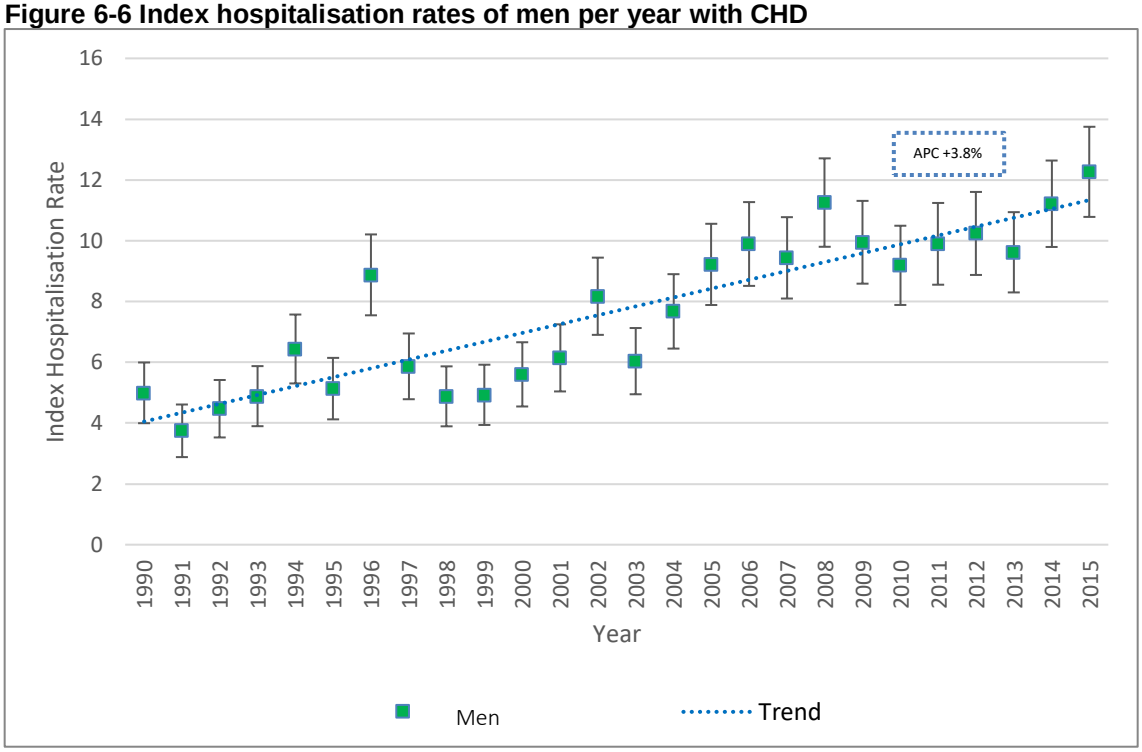
8 986 males with CHD had an index hospitalisation within the observed study period. Of this, 4 029 (45%) were men. For those over the age of 16 years, when standardised for the Scottish population of men over the age of 16 per year, there was an index hospitalisation rate of 5.0 (95% CI 4.0-6.0) per 100 000 in 1990 compared with 12.3 (95% CI 10.8-13.8) in 2015. The index hospitalisation rate ranged from 3.8 to 12.3 per 100 000.

The CHD index hospitalisation rate of men each year per 100 000 of the Scottish male population ≥16 is shown in Table 5, Appendix B and is displayed in Figure 6-6.

9 004 females with CHD had an index hospitalisation within the study period. Of this, 4 453(49.5%) were women. For women, index hospitalisation rate standardised to the Scottish population of females over the age of 16 per year increased from 4.5 (95% CI 3.6-5.3) in 1990, compared with 8.7 (95%CI 7.5-9.9) in 2015. The index hospitalisation rate ranged from 4.1 to 11.3 per 100 000.

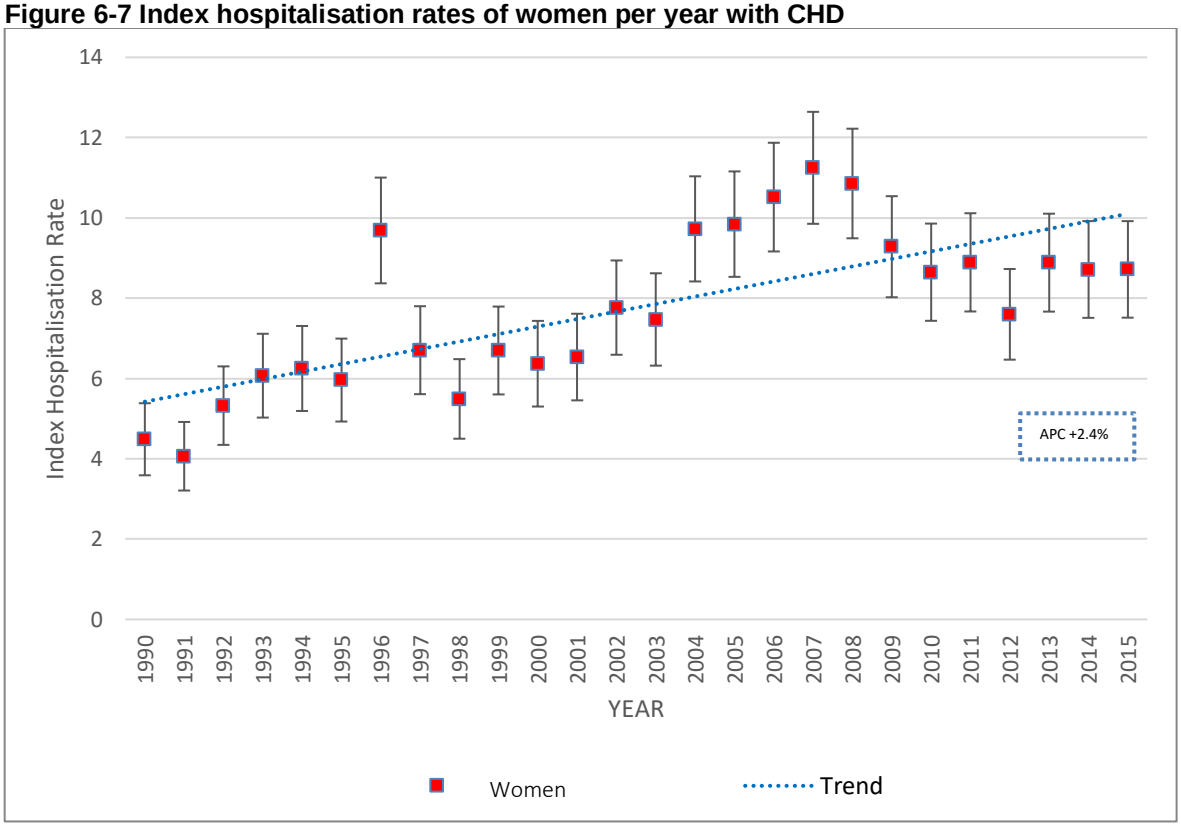
The CHD index hospitalisation rate of women with each year per 100 000 of the Scottish female population ≥16 is shown in Table 6, Appendix B and is displayed in Figure 6-7.

Figure 6-6 Index hospitalisation rates of men per year with CHD



Index hospitalisation rate per annum for men with CHD expressed as rate per 100 000 of the male population aged ≥16 years old. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

Figure 6-7 Index hospitalisation rates of women per year with CHD



Index hospitalisation rate per annum for women with CHD expressed as rate per 100 000 of the female population aged ≥16 years old. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

There was a 3.8% (95% CI 2.9 – 4.7%, p<0.05) annual increase in the index hospitalisation rate of men and a 2.4% (95% CI 1.3 – 3.5%, p<0.05) increase in the annual index hospitalisation rate of women.

6.3.4 Lesion Severity and Sex

6.3.4.1 Mild Complexity Lesions

There were 3 845 males with an index hospitalisation of a mild complexity lesion. This represents:

- 21.4% of the combined total hospitalisations
- 42.8% of the total number of hospitalised males
- 45.4% of the total number of lesions of mild complexity hospitalised

The index hospitalisation rates for males with lesions of mild complexity increased from 4.5 (95%CI 3.7-5.4) in 1990 to 6.4 (95%CI 5.5-7.4) in 2015. The index hospitalisation rate ranged from a 3.8 to 8.9 per 100 000.

The index hospitalisation rates for males with a lesion of mild complexity indexed to 100 000 of the Scottish male population is shown in Table 7, Appendix B and is displayed in Figure 6-8.

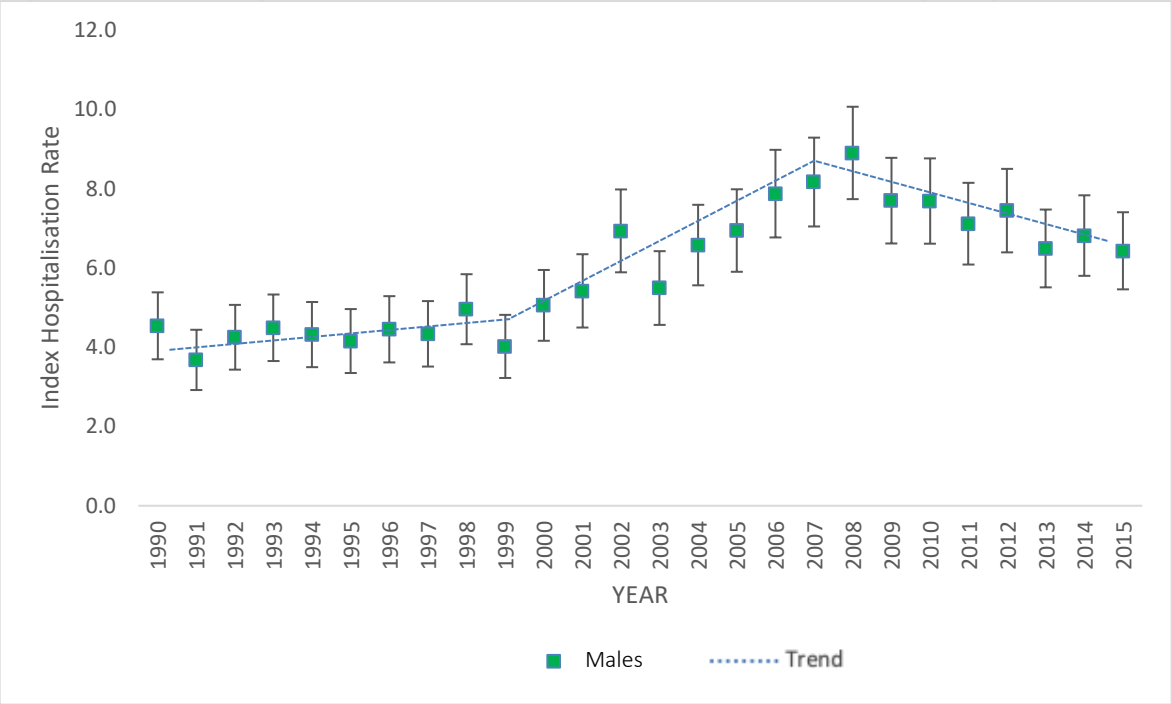
There were 4 613 females with an index hospitalisation of a mild complexity lesion. This represents:

- 25.6% of the combined total hospitalisations
- 51.2% of the total number of females hospitalised
- 54.5% of the total number of lesions of mild complexity hospitalised

The index hospitalisation rate for females increased from 4.7 (95% CI 41.2-58.2) in 1990 to 6.3 (95%CI 5.3-7.2) in 2015. The index hospitalisation rate ranged from 4.2 to 9.8 per 100 000.

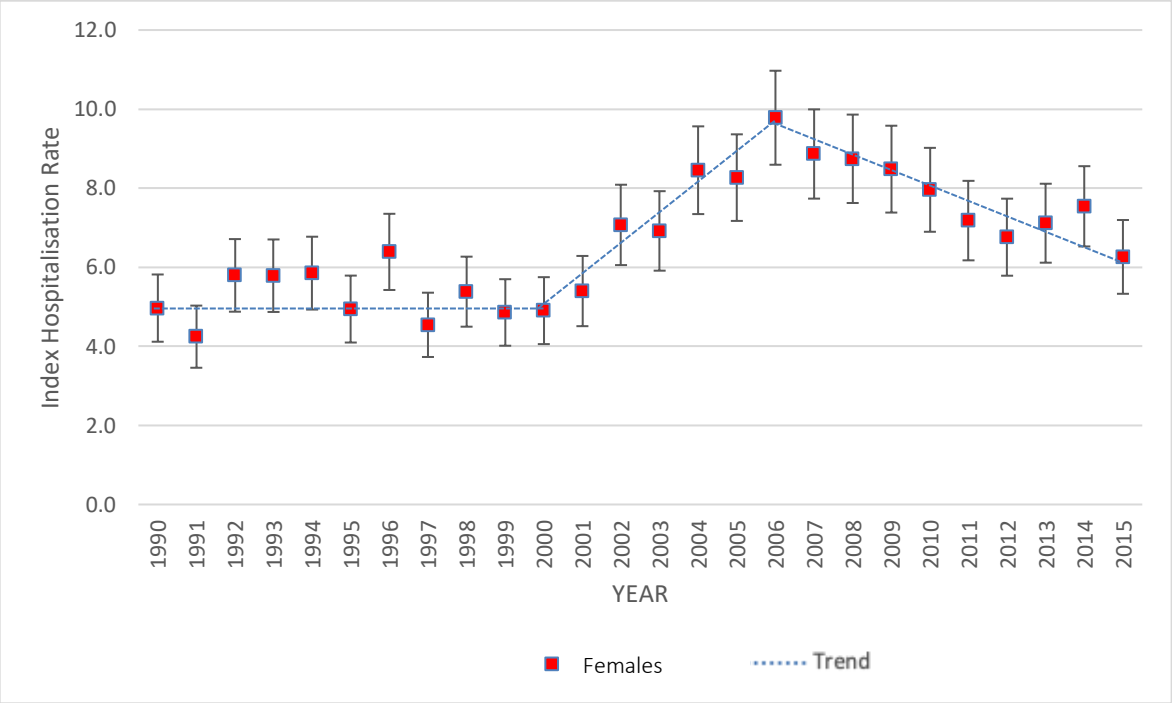
The index hospitalisation rate for females with a lesion of mild complexity indexed to 100 000 of the Scottish female population is shown in Table 8, Appendix B and is displayed in Figure 6-9.

Figure 6-8 Index hospitalisation rates for males with a lesion of mild complexity



Index hospitalisation rate per annum for males with CHD lesions of mild complexity expressed as rate per 100 000 of the male population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

Figure 6-9 Index hospitalisation rates for females with a lesion of mild complexity



Index hospitalisation rate per annum for females with CHD lesions of mild complexity expressed as rate per 100 000 of the female population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

There are 2 joinpoints to define the trend in both male and female with mild complexity index hospitalisations. Firstly, for males between 1990 and 1999 there was no change in annual index hospitalisation rates, the APC was 1.2% (95% CI -1.1-3.5, p=0.3). For females between 1990 and 2000 there was no change in the annual index hospitalisation rates, the APC was 0.1% (95% CI -2.6 – 2.5%, p=1.0). For males between the years 1999 and 2007 there was an annual increase in the index hospitalisation rate of 7.9% (95% CI 4.9-11.0, p<0.05) and for females between the years 2000 and 2006 there was an annual increase in the index hospitalisation rate of hospitalisation of 10.3% (95% CI 3.6 – 17.5%, p<0.05). This was then followed by an annual decrease in the index hospitalisation rate of 3.4% (95% CI -5.4—1.4, p<0.05) between the years 2007 and 2015 for males and 3.4% (95% CI -5.4 - -1.4%, p<0.05) between the years 2006 and 2015 for females.

6.3.4.2 Moderate Complexity Lesions

There were 3 303 males with an index hospitalisation of a moderate complexity lesion. This represents:

- 18.4% of the combined total hospitalisations
- 36.8% of the total number of male hospitalisations
- 55.7% of the total number of lesions of moderate complexity hospitalised

The index hospitalisation rates for males with lesions of moderate complexity increased from 5.1 (95% 4.28-6.0) in 1990 to 6.2 (95% 5.3-7.2) in 2015. The index hospitalisation rate ranged from 4.1 to 7.6 per 100 000.

The index hospitalisation rate of males hospitalised with a moderate complexity lesion indexed to 100 000 of the Scottish male population is shown in Table 9, Appendix B and is displayed in Figure 6-10.

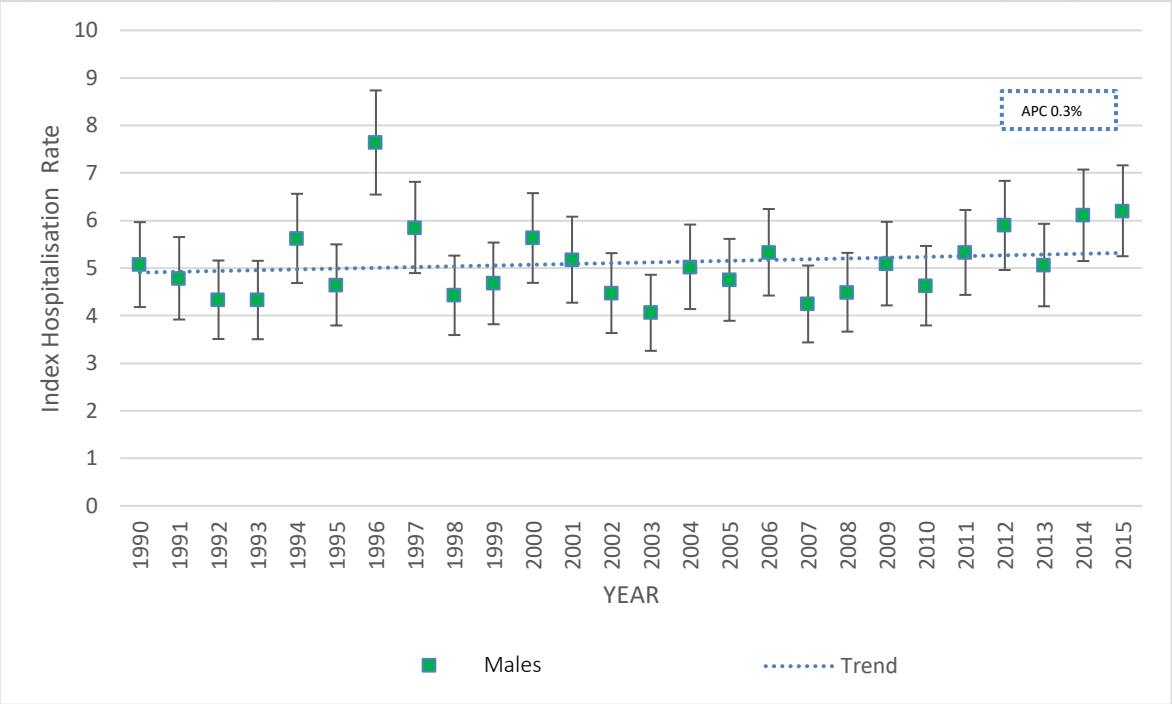
There were 2 756 females with an index hospitalisation of a moderate complexity lesion. This represents:

- 15.3% of the combined total hospitalisations
- 30.6% of the total number of female hospitalisations
- 44.3% of the total number of hospitalisations with a lesion of moderate complexity

The index hospitalisation rate for females ranged from 3.1 (95% CI 2.4-3.8) in 1990 to 4.0 (95% CI 3.2-4.7) in 2015. The hospitalisation rate ranged from 3.0 to 6.6 per 100 000.

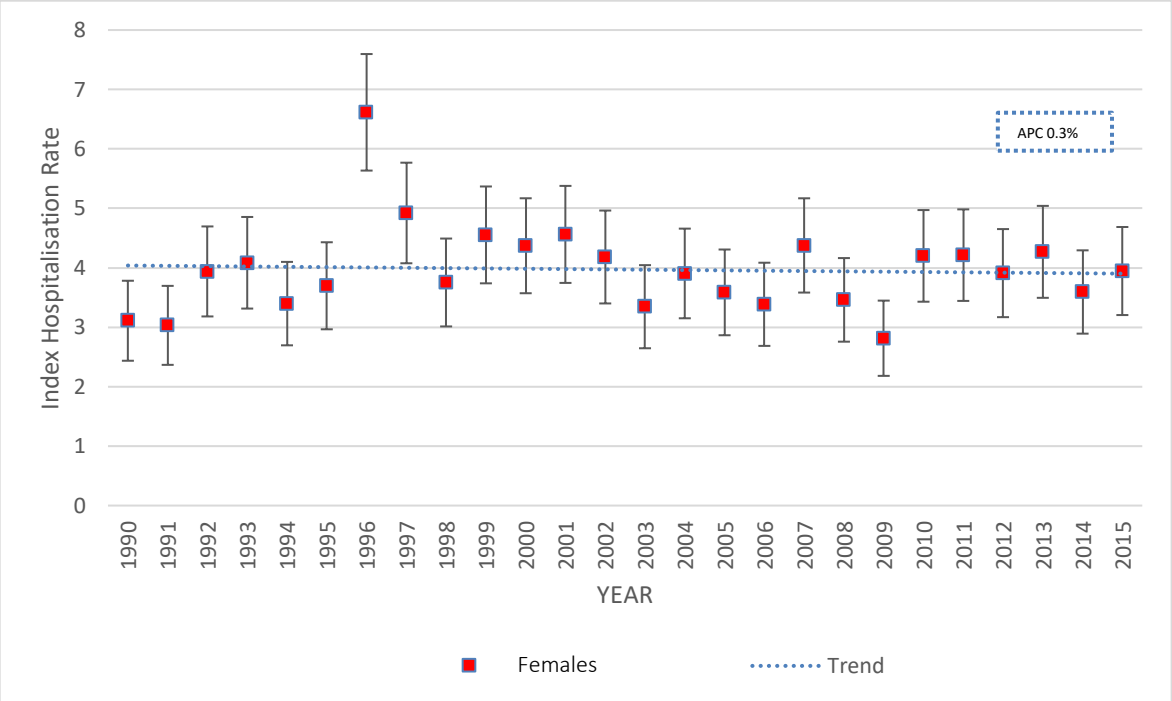
The index hospitalisation rate for females with a lesion of moderate complexity per year indexed to 100 000 of the of the Scottish female population is shown in the Table 10, Appendix B and is displayed in Figure 6-11.

Figure 6-10 Index hospitalisation rates for males with a lesion of moderate complexity



Index hospitalisation rate per annum for males with CHD lesions of moderate complexity expressed as rate per 100 000 of the male population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

Figure 6-11 Index hospitalisation rates for females with a lesion of moderate complexity



Index hospitalisation rate per annum for females with CHD lesions of moderate complexity expressed as rate per 100 000 of the female population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

There was no change in the annual index hospitalisation rate for males and females with lesions of moderate complexity. The APC was 0.3% (95% CI -0.5 – 1.1%, p=0.5) for males and 0.3% (95% CI -1.3 – 0.8%, p=0.6) for females.

6.3.4.3 Great Complexity Lesions

There were 971 males with an index hospitalisation of a lesion of great complexity. This represents:

- 5.4% of the combined total hospitalisations.
- 10.8% of the total number of male hospitalisations.
- 49.6% of the total number of lesions of great complexity hospitalised.

The index hospitalisation rates for males with lesions of great complexity increased from 1.6 (95% CI 1.1-2.1) in 1990 to 1.9 (95% CI 1.4-2.4) in 2015. The index hospitalisation rate ranged from 1.0 to 2.2 per 100 000.

The index hospitalisation rate of males each year with a lesion of great complexity per 100 000 of the Scottish male population is shown in Table 11, Appendix B and is displayed in Figure 6-12.

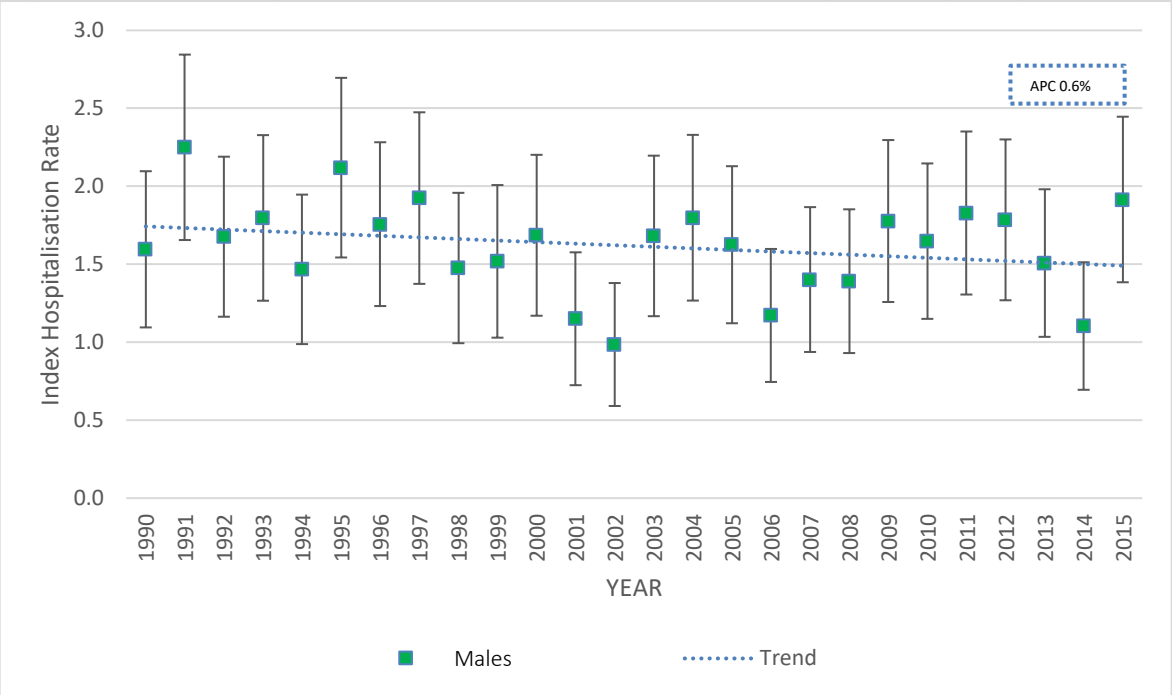
There were 986 females with an index hospitalisation of a lesion of great complexity. This represents:

- 5.5% of the combined total hospitalisations
- 11.0% of the total number of female hospitalisations
- 50.4% of the total number of lesions of great complexity hospitalised

The index hospitalisation rate for females with lesions of great complexity decreased from 1.6 (95% CI 1.1-2.1) in 1990 to 1.4 (95% CI 0.9-1.8) in 2015. The index hospitalisation rate ranged from 0.6 to 1.6 per 100 000.

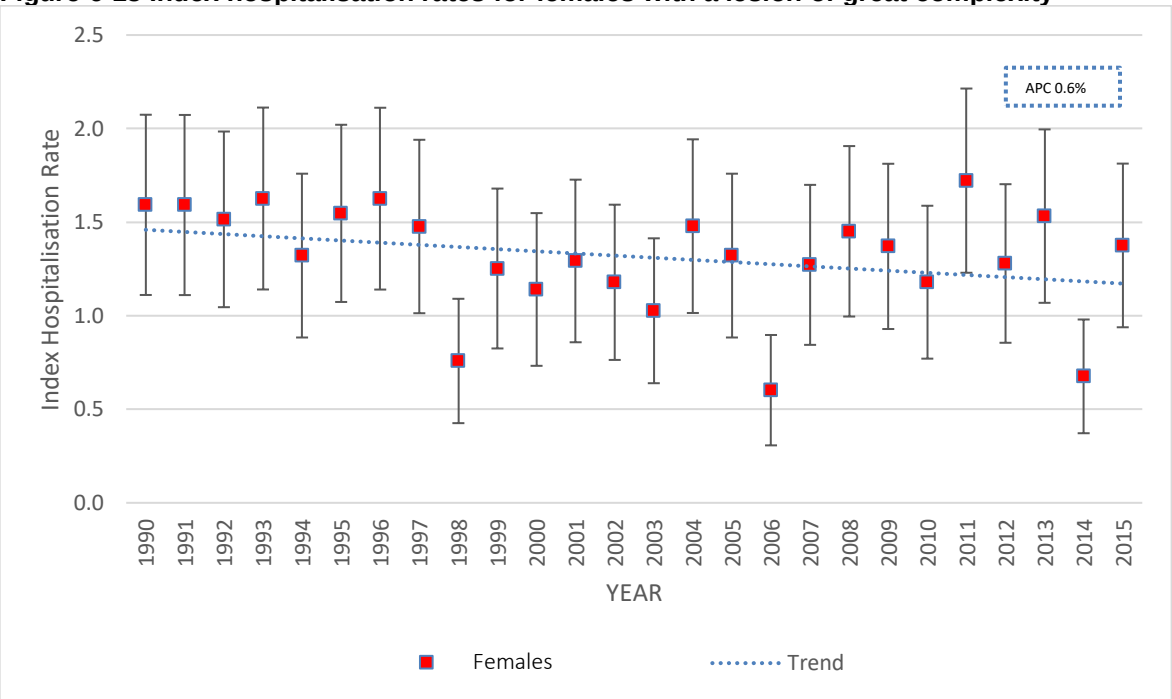
The index hospitalisation rate of females per year with a CHD lesion of great complexity per 100 000 of the Scottish female population is shown in the Table 12, Appendix B and is displayed in Figure 6-13.

Figure 6-12 Index hospitalisation rates for males with a lesion of great complexity



Index hospitalisation rate per annum for males with CHD lesions of great complexity expressed as rate per 100 000 of the male population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

Figure 6-13 Index hospitalisation rates for females with a lesion of great complexity



Index hospitalisation rate per annum for females with CHD lesions of great complexity expressed as rate per 100 000 of the female population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

There was no change in the annual index hospitalisation rate for males and females with lesions of great complexity. The APC was 0.6% (95% CI -1.5 – 0.3%, p=0.2) for males and 0.6% (95% CI -1.5 – 0.2%, p=0.2) for females.

6.3.5 APC summary

Table 6-2 contains a summary of the APC for both sexes with respect to all index hospitalisations, age and underlying lesion complexity. Where there were multiple joinpoints in the APC temporal trend one should refer to the corresponding figure for that cohort. A significant increase ($p<0.05$) in the APC is prefixed by a "+" and a significant decrease ($p<0.05$) in the APC is prefixed by a "-".

Table 6-2 Summary table of the APC in males and females for all index hospitalisations, ages and CHD lesion complexity.

	Sex	Index Hospitalisations (n)	Annual Percentage Change
All	Male	8 986	+1.7
	Female	9 004	+1.3
Ages	Boys	4 957	No change
	Girls	4 551	+0.8
	Men	4 029	+3.8
	Women	4 453	+2.4
Mild Lesion Complexity	Male	3 845	Multiple joinpoints
	Female	4 613	Multiple joinpoints
Moderate Lesion Complexity	Male	3 303	No change
	Female	2 756	No change
Great Lesion Complexity	Male	971	No change
	Female	986	No change

+ significant increase in APC, p<0.05; - significant decrease in APC, p<0.05

6.4 Discussion

6.4.1 Baseline Characteristics

In this Chapter I have described 8 986 males and 9 004 females who had an index hospitalisation in Scotland between 1990 and 2015 with a diagnosis of CHD. When indexed to the Scottish population of males and females in 2015, this provides a crude prevalence of 3.3 per 1 000 in males and 3.4 per 1 000 in females. This is below the published estimates (4.8 and 3.9 per 1 000 of the Quebec population for females and males respectively) and is possibly a result of the underestimation of mild lesions in my study where a hospitalisation was a requirement for inclusion in the data, whereas many of these lesions may have been managed in an outpatient setting.

Females were older at time of index hospitalisation (27 years) compared to males (23 years). This finding is consistent with the findings outlined in the literature review.

As discussed in the previous Chapter, index hospitalisations among certain lesions appeared to be higher among some sexes. Women had more index hospitalisations with diagnoses of ASD, PDA, Ebstein's and AVSD, whereas men had more index hospitalisations with ToF, TGA arterial switch, Fontan and congenital valvular defects. This distribution between the sexes is in keeping with sex-specific lesion hospitalisations and incidence outlined within the literature review.

More females than males live in areas with higher levels of SED with 28.2% ($p<0.05$) of females and 25.7% of males with an index hospitalisation in my study cohort residing in SIMD1 (most deprived). There was no difference between the proportion of females and males (51.3% Vs 48.7%, $p=0.2$) with an index hospitalisation in the in SIMD5 (least deprived). In the general population, there is no difference noted in sex prevalence in SIMD1 with an equal share of approximately 20% of both sexes. This indicates that not only are patients with CHD more likely to reside in higher levels of deprivation than the general population, but that females with CHD are more likely to reside in areas of

higher SED compared to males. The reason for this disparity is not clear and will be reviewed further in Chapter 8.

6.4.2 Overall Index Hospitalisations

There is no difference in the number of index hospitalisations between the sexes over the study period, with a total of 8 986 male and 9 004 female (49.9% Vs 50.1%, p=0.79) index hospitalisations. A similar finding was reported by Verheugt et al. [107] who reported in a Dutch registry that woman made up 49.8% of their CHD study population.

When hospitalisation is indexed to 100 000 of the Scottish population for both sexes, there is a statistically significant increase in the APC of the index hospitalisation rates in both females (1.3%, $p<0.05$) and males (1.7%, $p<0.05$), indicating that the rate of index hospitalisation is increasing for both sexes over time. There was no difference in the annual index hospitalisation rates between the sexes with overlapping confidence intervals for the APC. Islam et al.[62] found a similar trend in the increase of the annual hospitalisation rate of 1.5% per year in males and 0.7% in females, with a consistently higher rate observed among males in their cohort.

Statistics from PHS reporting annual hospitalisation (and not inpatient episodes) in the general population of Scotland is available from 2011 onwards.[90] This data shows that there was an increase in the number of female hospitalisations of any medical condition from 620 547 in 2011 to 656 577 in 2015 with a 1.2% (0.9 – 1.4%, $p<0.05$) annual increase in the hospitalisation rate of females. With comparison to the female CHD index hospitalisation rate, there was no difference between the APC in both cohorts. Male hospitalisations of any medical condition increased from 549 262 in 2011 to 582 195 to 2015 with a 1.2% (0.7 – 1.6%, $p<0.05$) annual increase in the hospitalisation rate of males. With comparison to the male CHD index hospitalisation rates, there is no difference between the APC of both groups. One may expect to find that if all CHD hospitalisations in Scotland were analysed then the hospitalisation rates of both male and females with CHD would be higher than that of the general population.

6.4.3 Sex and Age

Index hospitalisations over the observed period for both sexes of children were similar, although there were more boys than girls hospitalised over the study period (52.1%, $p<0.05$). One possible explanation of this is that there is an increased incidence of lesions of moderate and great complexity within males including ToF, TGA switch, SRV and Fontan. These lesions are more likely to require hospitalisation at a younger age. Consequently, index hospitalisation for boys would be observed at a younger age.

There was an increase in the index hospitalisation rate for girls but not in boys (girls APC 0.8%, $p<0.05$ and male children APC 0.7%, $p=0.9$). This small but increasing trend in CHD among girls during 1990 - 2015 has been demonstrated in other studies, both in Europe and worldwide.[108,109] The reasons for this has been discussed in Chapter 5, but in essence is thought to be due to the increased rate of diagnosis of lesions of mild complexity in infancy and the surrounding years, which are thought to be more common among females.

More women than men had an index hospitalisation over the study period (52.5%, $p<0.05$). There was a statistically significant increase in the trend of adult index hospitalisation rate in both sexes (women APC 2.4%, $p<0.05$ and men APC 3.8%, $p<0.05$). The APC of the hospitalisation rate for the general adult population within Scotland over the same period was 1.1% (95% CI 0.8 – 1.5%, $p<0.05$) which was significantly lower than that of the study population, indicating that the index hospitalisation rates of patients with CHD is higher than that of the general population within Scotland during the study period.

The higher index hospitalisation rates observed among women appear to be driven by an increase in the rates of mild lesion complexity. Rodrigues et al.[65] found that the incidence of septal defects (mild lesions) was higher among females than males, and as these shunt lesions tend to present in later life due to progressive volume loading of the right heart, then this may offer an explanation as to the increased index hospitalisation rates seen among women.

6.4.4 Lesion Severity and Sex

There were more index hospitalisations of females (54.5%, $p<0.05$) with lesions of mild complexity observed compared to males. ASDs are included in the mild lesion complexity grouping. The larger number of hospitalisation among females may be explained by the increased prevalence of ASD in females when compared to males.[110] The index hospitalisation rate trends for both sexes show a similar pattern of a steady line during the period of 1990 to 2000, before a sharp increase in index hospitalisation rates to 2006, before a flattening in the increase again, and is likely a reflection in the changes in ASD diagnosis. A possible explanation for this trend has been offered in the previous chapter regarding PFO closure in the early 2000s.[100] PFO share an ICD code with ASD, and are indistinguishable from each other on the basis of coding without the clinical notes or access to cardiac imaging. This has been discussed elsewhere in Chapter 5.

There were more index hospitalisations of males with lesions of moderate complexity compared to females (54.5%, $p<0.05$) over the study period. Aortic lesions, ToF and TGA have been shown to have a male predisposition in previous studies of live birth incidence of CHD and may offer an explanation of the increased number of male when compared to female hospitalisations in the lesions of moderate complexity.[80] There have been several factors that have been hypothesised but no explanation for these gender differences in CHD lesions has been demonstrated.

There was no change in the index hospitalisation rates for lesions of moderate complexity over the study period (male APC 0.3%, $p=0.5$ and female APC 0.3%, $p=0.6$). Islam et al. and Mackie et al.[61,62] also found that those patients with lesions of moderate complexity had stable hospitalisation rates during their respective study periods of study between 2003 and 2012 and 2004 and 2014 respectively. Although no cause has been demonstrated for this, a possible explanation is that during the time period of my study the diagnostic rate of the lesions comprising moderate complexity will not have changed with most moderate complexity lesions 'apparent' at birth or shortly thereafter. A consistent approach to operative techniques used in repair of these lesions will have been present over the course of my study, whereas for lesions of great

complexity, the change in the surgical techniques and the care within the neonatal intensive care environment will have changed substantially.

There was no difference in the number of male and female index hospitalisations with lesions of great complexity (49.6% Vs 50.4%, p=0.7) over the study period. There was no change in the annual index hospitalisation rates for both males and females among lesions of great complexity (APC 0.6%, p=0.2). CHD lesions of great complexity such as HLHS, tricuspid atresia as well as pulmonary atresia and VSD are known to affect males more frequently than females[111] and one would expect to observe a higher hospitalisation rate among males in this group. This is likely as a result of the study design to analyse index hospitalisations and not all hospitalisations. It is recognised that males are likely to develop more complications or have more co-morbid conditions compared to females[107]. Females may experience lower mortality compared to males[112]. Males are more likely to undergo surgery in adulthood and have poorer outcome after repeated surgical procedures compared to females.[112,113]

The year 1996 again appears to be a significant outlier with respect the surrounding years in men and women and in lesions of moderate severity index hospitalisations. The explanations for this have been postulated in Chapter 5 and relate to changes in versions of the ICD.

6.5 Conclusion

Index hospitalisation rates in both sexes is increasing at a significant rate, driven by increasing rate of mild complexity lesion index hospitalisations. There appears to be sex specific variation in the rate of index hospitalisation among boys and girls as well as men and women. The index hospitalisation rate amongst females with mild complexity CHD lesions is higher than that of males, whereas index hospitalisation rates among males is higher in lesions of moderate complexity. There was no difference in index hospitalisation between males and females in lesions of great complexity.

More than half of the observed index hospitalisations were in patients of paediatric age. In the next Chapter I will explore the age-specific rates of index hospitalisation for CHD in Scotland.

7 Age

7.1 Introduction

99% of infants are born in hospital in Scotland[114] and as such those infants have an index hospitalisation, creating a CIS and source for diagnostic coding of specific diagnoses or conditions. I can review this by censoring the data for those patients with an index hospitalisation, age=0 years (infants).

There is no set age at which children with CHD transition to the adult services. Transition of care is usually a shared decision process involving clinicians, parents and most importantly the patient. For the purpose of this thesis, I am using the age <16 years old to identify children, and those ages 16 and older as adults. Although using 16 as a cut off is somewhat different from what is used by those studies in the literature review, it reflects more what real-life practice is like within Scotland.

Although not specifically demonstrated in the literature, one can presume that in those adults over the age of 60, acquired valvular lesions are more likely than true congenital valvular lesions. Labelling of congenital valvular lesions (without access to clinical notes and imaging) at this point may reflect mistaken diagnostic coding rather than true CHD and as such, over-estimate the true incidence of CHD in this population. The same argument may also be used for those over the age of 60 with a PFO, which has an estimated adult incidence of 25%[115]. Thus far, only trials in those aged <60 have demonstrated that percutaneous closure of PFO results in reduction of recurrent stroke, versus medical therapy alone[116–120]. Those aged ≥60 are more likely to have morbidity secondary to an acquired condition, or unrelated cardiac defect, with incidental finding of a PFO. However, for haemodynamically significant ASDs there is clear benefit that both surgical repair and percutaneous closure is of benefit in those aged ≥60[121–123]. As previously discussed, I cannot separate PFO and ASD based on ICD diagnosis or OPCS without access to clinical notes or imaging. As such I investigate those adults aged ≥60 with and without a diagnosis of PFO/ASD and valvular heart lesions.

In this Chapter I describe the index hospitalisation of patients with CHD through the years 1990 – 2015 in the following groups:

- Infants
- Children
- Adults
- Adults ≥60 with and without diagnoses of ASD and valvular lesions included.

Sex-related index hospitalisations of both men, boys, women and girls have been described previously in Chapter 6.

7.2 Methods

The methods used within this Chapter are as outlined in Chapter 3. The age definition of infants are those patients aged <1 year, children are those aged 1 – 15. The term paediatric refers to all patients <16 years, adults are those aged ≥16 years. Two subsets of adults will also be described, young adults 20 – 59 years and older adults aged ≥60 years.

7.3 Baseline Characteristics

A table summarising the baseline characteristics of all individuals as well for adult and paediatric index hospitalisations is found in Table 7-1.

Table 7-1 Summary of baseline characteristics for both sexes.

	All	Adults (%)	Paediatric (%)	p-value
Hospitalisations, n (%)	17 990 (100)	8 482 (100)	9 508 (100)	<0.05
Median Age, years	25	52	2	
Sex (%)				
Male	8 986 (49.9)	4 029 (47.5)	4 957 (52.1)	<0.05
Female	9 004 (50.1)	4 453 (52.5)	4 551 (47.9)	<0.05
SIMD, n (%) [p-value]				
1 (most deprived)	4 849 (27.2)	2 073 (24.4)	2 776 (29.2)	<0.05
2	3 827 (21.4)	1 809 (21.3)	2 015 (21.2)	<0.05
3	3 339 (18.7)	1 614 (19.0)	1 725 (18.1)	<0.05
4	3 019 (16.9)	1 491 (17.6)	1 528 (16.1)	<0.05
5 (least deprived)	2 818 (15.8)	1 426 (16.8)	1 392 (14.6)	<0.05
Lesion, n (%)				
ASD	4 184 (23.2)	3 090 (36.4)	1 094 (11.5)	<0.05
PDA	1 707(9.5)	104 (1.2)	1 603 (16.9)	<0.05
VSD	2 567 (14.3)	839 (9.9)	1 728 (18.2)	<0.05
AVSD	866 (4.8)	201 (2.4)	665 (7.0)	<0.05
Aortic	2 003 (11.1)	1 168 (13.8)	835 (8.8)	<0.05
Ebstein's	120 (0.7)	71 (0.8)	49 (0.5)	<0.05
ToF	781 (4.3)	109 (1.3)	672 (7.1)	<0.05
TGA	220 (1.2)	0 (0.0)	220 (2.3)	<0.05
SRV	123 (0.7)	15 (0.2)	108 (1.1)	<0.05
Fontan	216 (1.2)	17 (0.2)	199 (2.1)	<0.05
Valvular	2 069 (11.5)	1 304 (15.4)	765 (8.0)	<0.05
Complex	1 618 (9.0)	348 (4.1)	1 270 (13.3)	<0.05
Other	1 516 (8.4)	1 216 (14.3)	300 (3.2)	<0.05
Lesion Complexity, n (%)				
Mild	8 458 (47.0)	4 033 (47.5)	4 425 (46.5)	<0.05
Moderate	6 059 (33.7)	2 853 (33.6)	3 206 (33.7)	<0.05
Great	1 957 (10.9)	380 (4.5)	1 577 (16.6)	<0.05

A total of 17 990 index hospitalisation were observed over the study period. Of that 8 482 (47.1%) were adults and 9 508 (52.9%) were paediatric patients, $p<0.05$. The median age at index hospitalisations for all patients was 25 years, whereas as expected this was older in the adult age group (52 years) and younger among the paediatric groups (2 years).

A greater proportion of the adult cohort were female compared to male (52.5%, $p<0.05$). There were less paediatric females (25.3%) compared to males (47.9%, $p<0.05$).

Paediatric patients more often resided in a postcode that was associated with a higher incidence of SED (SIMD1) compared to adults, 15.6% and 11.6% ($p<0.05$) respectively.

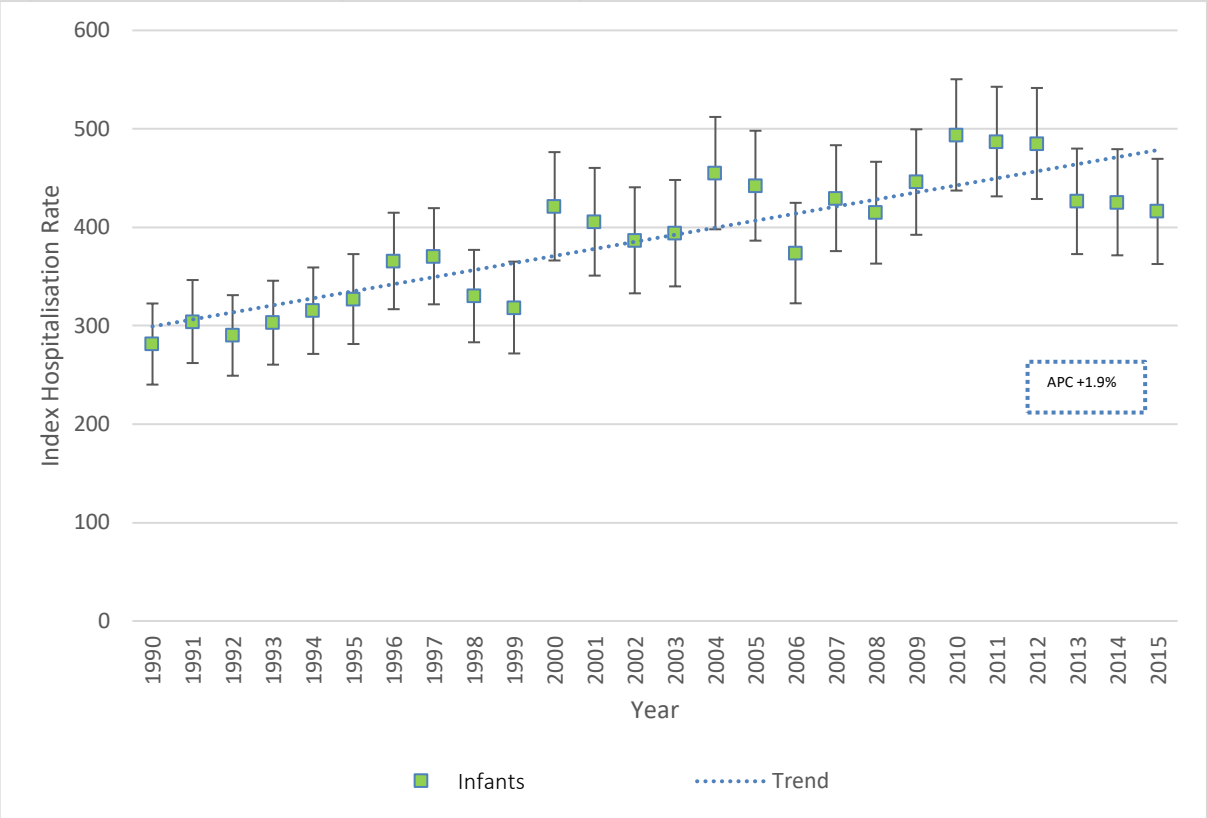
There were differences between the incidence of index hospitalisation among the lesion groups. Paediatric hospitalisations had higher incidence of PDA (16.9%, $p<0.05$), VSD (18.2%, $p<0.05$), AVSD (7.0%, $p<0.05$), ToF (7.1%, $p<0.05$), TGA (2.3%, $p<0.05$), SRV (1.1%, $p<0.05$), Fontan (2.1%, $p<0.05$) and complex lesions (13.3%, $p<0.05$). Whereas adults had higher incidence of index hospitalisations of ASD (36.4%, $p<0.05$), Aortic (13.8%, $p<0.05$), Ebstein's (0.8%, $p<0.05$) valvular (15.4%, $p<0.05$) and other lesions (14.3%, $p<0.05$).

7.4 Infants, Children and Adults

7.4.1 Infant Index Hospitalisation

Over the study period 1990 - 2015, a total of 5 838 infants (age <1 years) had an index hospitalisation with a diagnosis of CHD, representing a 32.5% of the total number of hospitalisations. When hospitalisations are indexed to the Scottish infant population, index hospitalisation rates can be generated. The index hospitalisation rate per 100 000 of the Scottish infant population ranged from 281.4(95% CI 240.1-322.6) in the year 1990 to 416.1(95% CI 362.6-469.5) in 2015. Index hospitalisation rates per 100 000 age matched Scottish population age=0 for the period 1990-2015 is shown in Table 1, Appendix C and is displayed and is displayed in Figure 7.1.

Figure 7-1 Infant index hospitalisation rate of patients with CHD



Index hospitalisation rate per annum for infants (age<1 years) with CHD expressed as rate per 100 000 of the infant population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

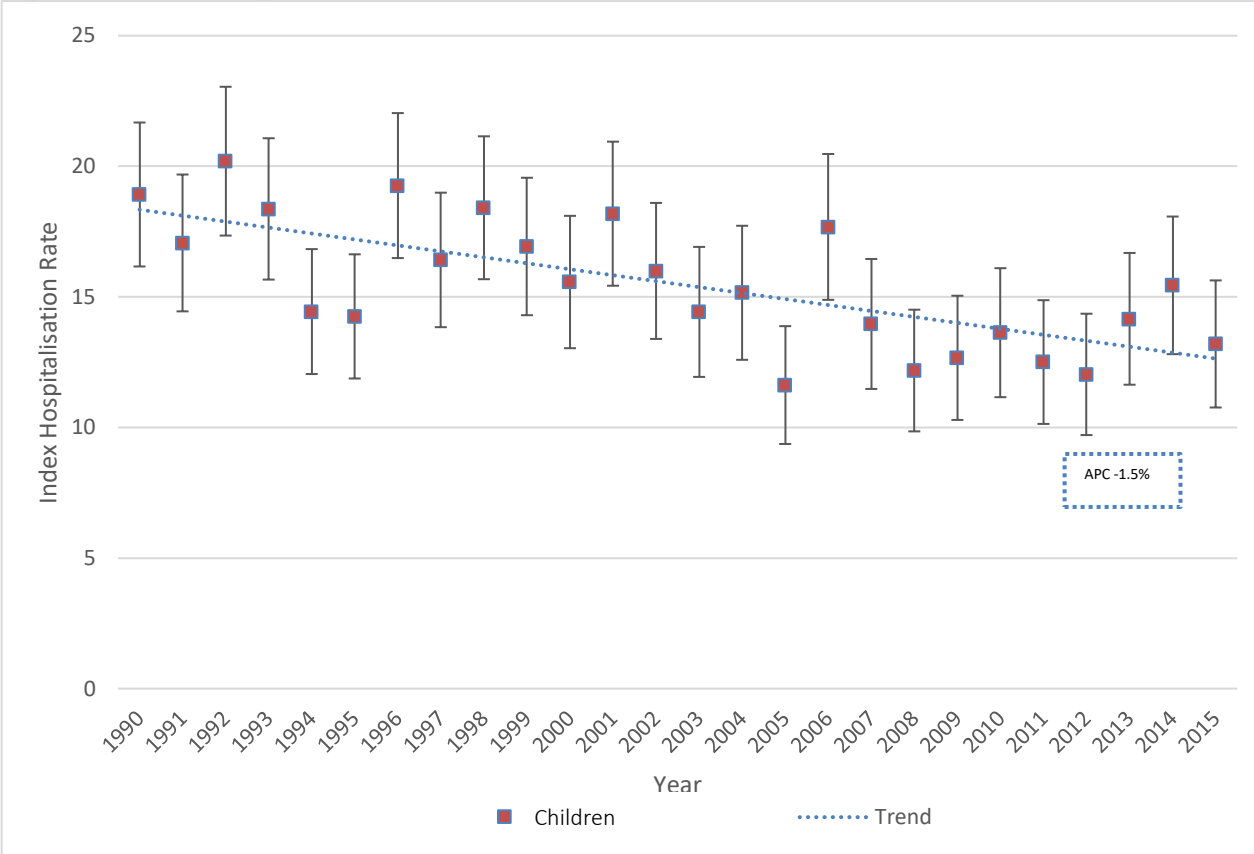
There was a 1.9% (95% CI 1.4 – 2.4%, p<0.05) annual increase in the index hospitalisation rate of infants over the study period.

7.4.2 Child Index Hospitalisations

Between the years 1990 – 2015, 3 670 patients aged between 1 and 15 years old (children) had an index hospitalisation with a diagnosis of CHD. This represents 20.4% of the total hospitalisation over the observed period. The age-standardised index hospitalisation rate for children aged 1-15 years varied from 18.9 (95% CI 16.2-21.7) per 100 000 of the population in the year 1990 to 11.6 (95% CI 9.4-13.9) in the year 2015.

The annual age-standardised index hospitalisation rates per 100 000 of the Scottish population is shown in Table 2, Appendix C and is displayed in Figure 7-2.

Figure 7-2 Index hospitalisation rate of children with CHD



Index hospitalisation rate per annum for children (age 1-15 years) with CHD expressed as rate per 100 000 of the Scottish children population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

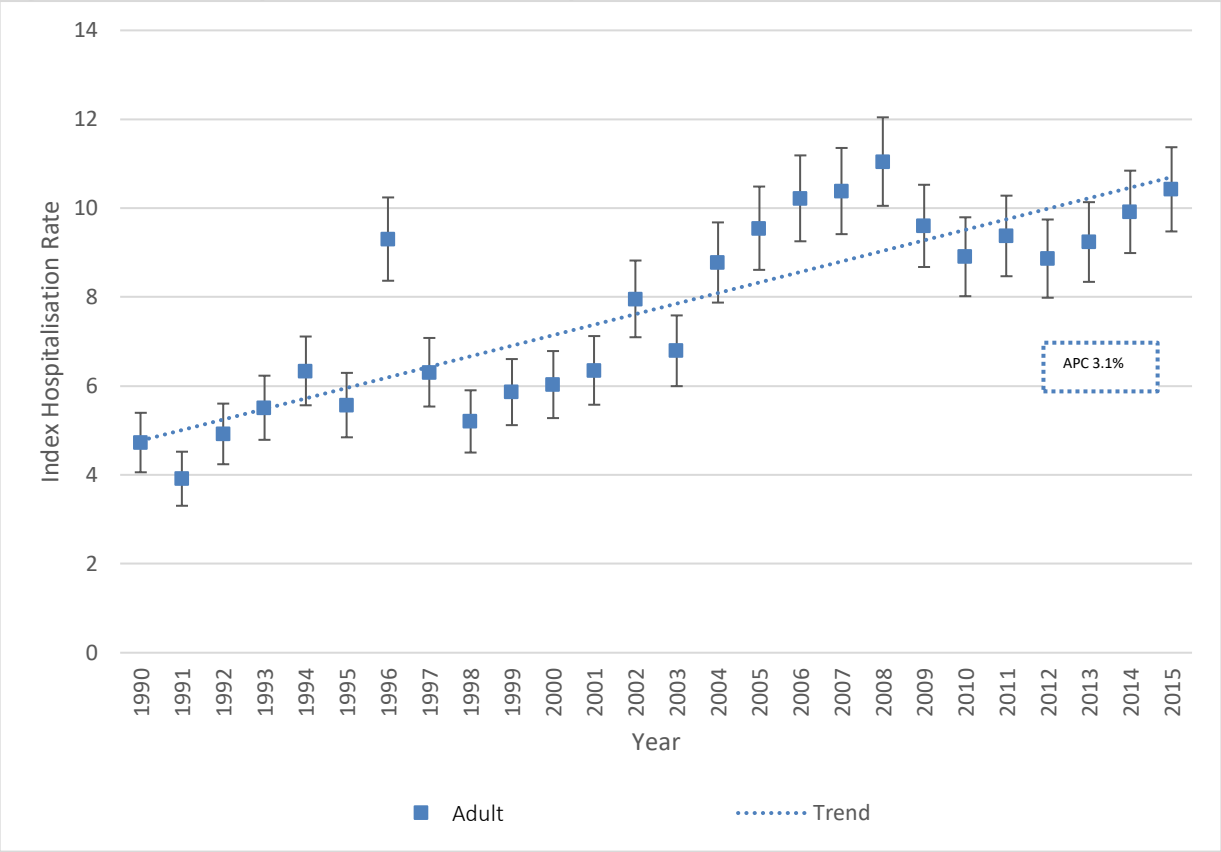
There was a 1.5% (95% CI -2.1 - -0.8%, p<0.05) annual decrease in the index hospitalisation rate for children aged 1-15.

7.4.3 Adult Index Hospitalisations – ages ≥16 years

Between the years 1990 – 2015, 8 482 patients aged ≥16 with a diagnosis of CHD had an index hospitalisation. Adult index hospitalisations are the largest of the age grouping, representing 47.1% of the total hospitalisations during the observed period. The index hospitalisation rate for adult patients varied from 4.7 (95% 4.1-5.4) per 100 000 of the Scottish adult population in the year 1991, to 11.0 (95% CI 10.1-12.0) per 100 000 in the year 2008.

Adult index hospitalisation rates per 100 000 of the Scottish population for those years is shown in Table 3, Appendix C and is displayed in Figure 7-3.

Figure 7-3 Index hospitalisation rate of adult patients with CHD



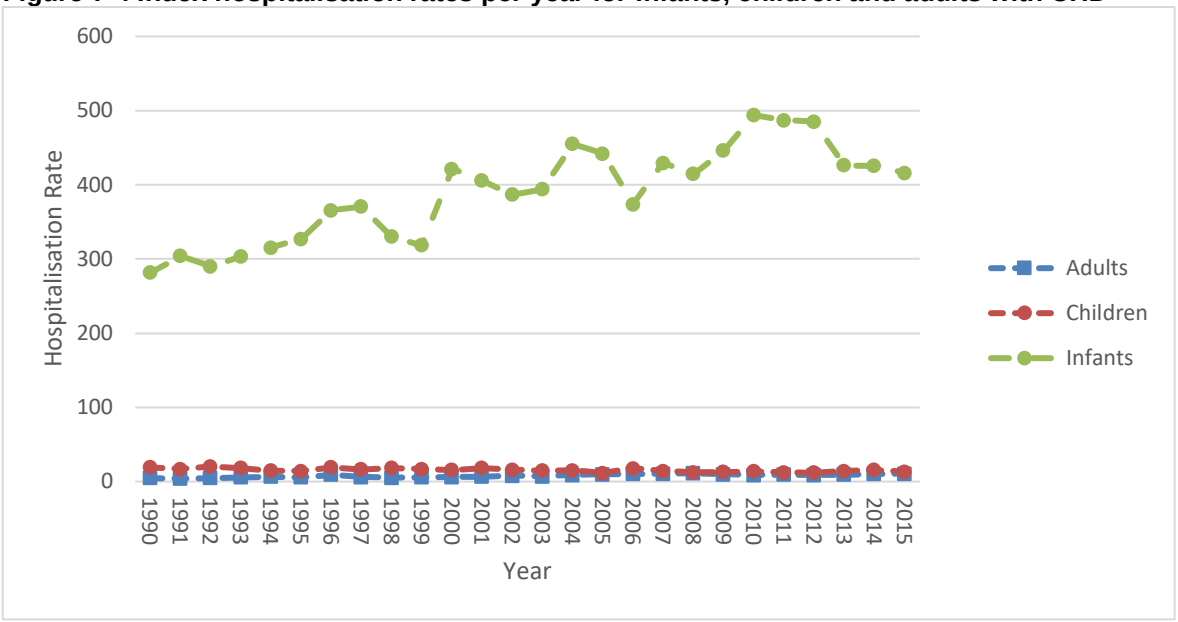
Index hospitalisation rate per annum for adults (age≥16 years) with CHD expressed as rate per 100 000 of the adult population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

There was a 3.1% (95% CI 2.1 – 4.0%, p<0.05) annual increase in the index hospitalisation rate of adults over the study period.

7.4.4 Infants, Children and Adults

To allow comparison of the index hospitalisation rates of the 3 ages groups described thus far, index hospitalisation rates of infants, children and adults is shown in Figure 7-4.

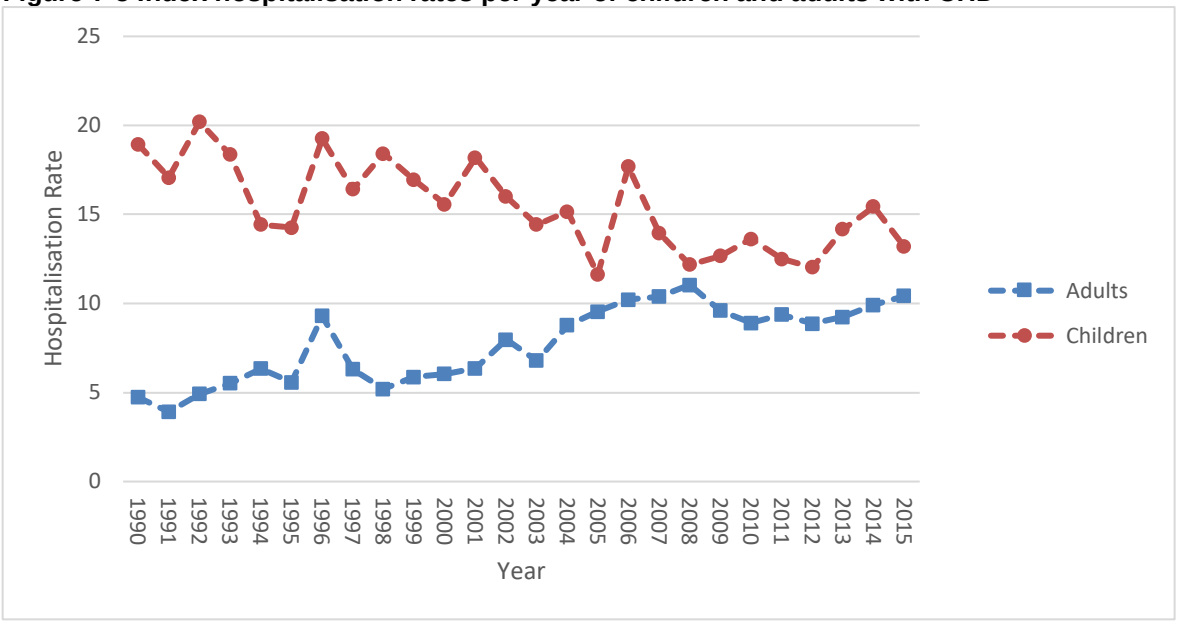
Figure 7-4 Index hospitalisation rates per year for infants, children and adults with CHD



Index hospitalisation rate per annum for infants, children and adults with CHD expressed as rate per 100 000 of their respective age matched population. The green circles represent index infant hospitalisation rates. The red circles represent index children hospitalisation rates. The blue squares represent index adult hospitalisation rate.

The index hospitalisation rates of infants range from 280 to 490 per 100 000 of the Scottish infant population. This is significantly higher than that of adults and children, which ranged from 3.9 – 20.2 per 100 000 of their age matched populations. Due to the scale and significantly higher index hospitalisation rate among infants compared to that of children and adults, it is difficult to appreciate the subtleties in the differences between adults and children. To demonstrate this, Figure 7-5 allows comparison of adults and children only.

Figure 7-5 Index hospitalisation rates per year of children and adults with CHD



Index hospitalisation rate per annum for children and adults with CHD expressed as rate per 100 000 of their respective age matched population. The red circles represent index children hospitalisation rates. The blue squares represent index adult hospitalisation rate.

7.5 Adult Index Hospitalisation

By the age of 20, all individuals with CHD will have transitioned into the services that provide continuing care for adults with CHD through the rest of their adult lives. I therefore will analyse adult index hospitalisations in 2 separate age categories

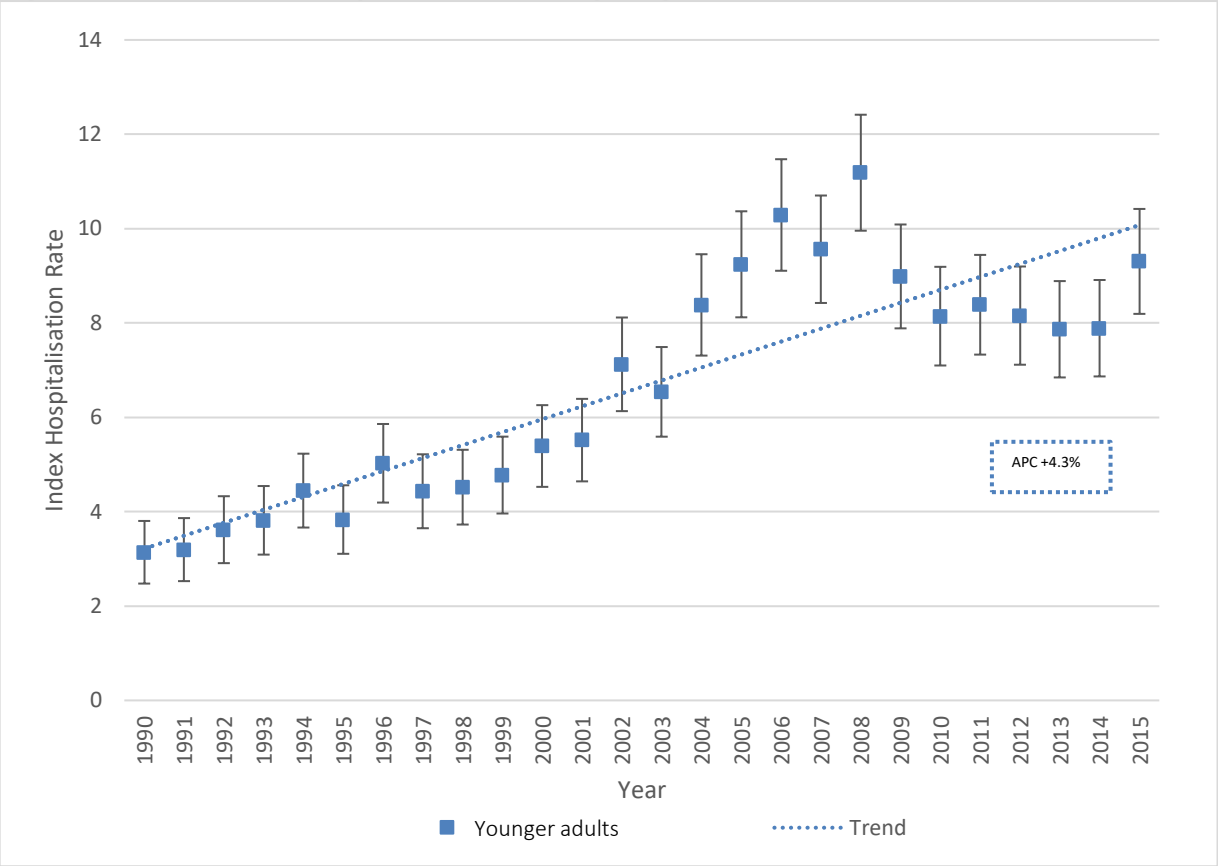
- Younger adults: Aged 20 – 59
- Older adults: Aged ≥60

7.5.1 Younger Adults – ages 20-59

4 880 younger adults had an index hospitalisation with CHD during the observed years. This represents 27.1% of the total hospitalisations. The index hospitalisation rate ranged from 3.1(95%2.5-3.8) in 1990 to of 9.3(95% 8.2-10.4) in 2015 per 100 000.

The index hospitalisation rate (per 100 000 of the Scottish population aged between 20 – 59 years old) per annum is shown in Table 4, Appendix C and is displayed in Figure 7-6.

Figure 7-6 Annual index hospitalisation rate of younger adults with CHD



Index hospitalisation rate per annum for younger adults (age 20-59 years) with CHD expressed as rate per 100 000 of the younger adult general population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

There was a 4.3% (95% CI 3.1 – 5.6%, p<0.05) annual increase in the hospitalisation rate of younger adults over the study period. Joinpoint regression models did not demonstrate a significant difference in the trend, with a linear trendline providing the best overall fit.

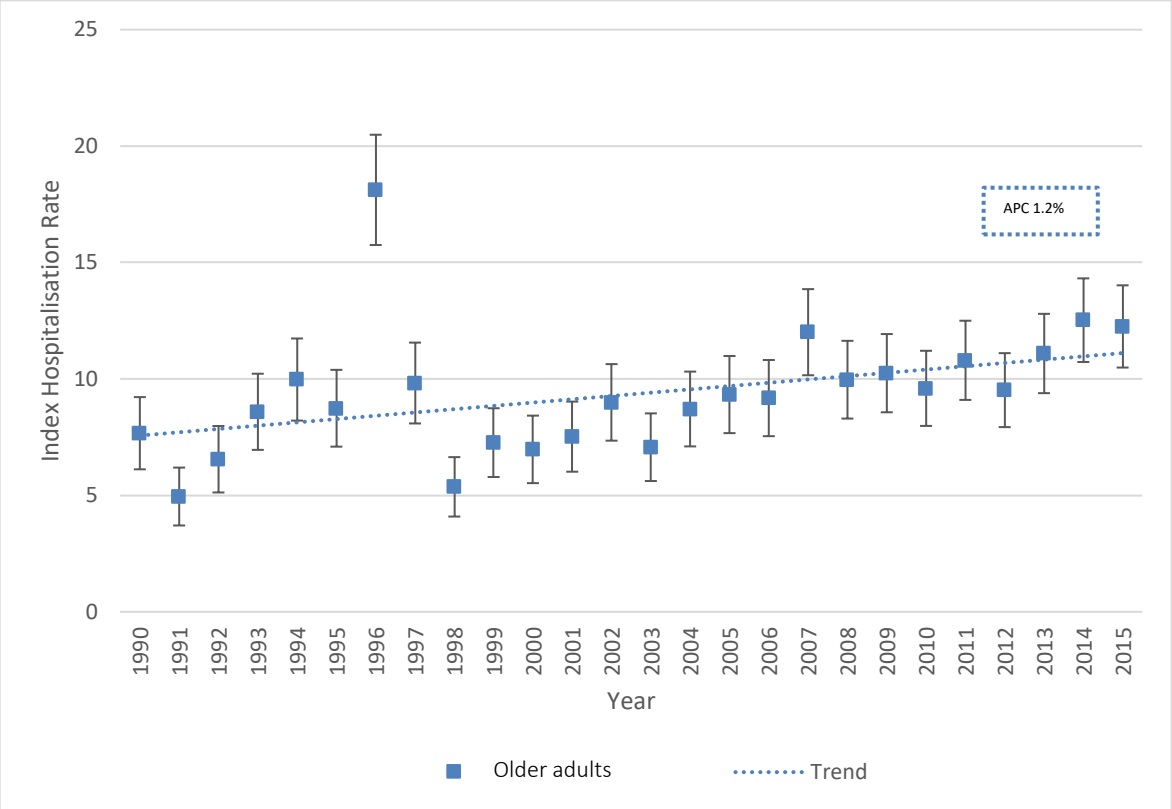
7.5.2 Older Adults – ages ≥60

7.5.2.1 Older Adults (including all lesion groups)

3 235 individuals had an index hospitalisation with CHD during the study period. This represents 18.0% of the total hospitalisations. The index hospitalisation rate ranged from 7.7(95% CI 6.1-9.2) in 1990 to 9.3(95% CI 10.5-14.0) in 2015 per 100 000.

The index hospitalisation rate (per 100 000 of the Scottish population aged ≥60 years old) per annum is shown in Table 5, Appendix C and is displayed in Figure 7-7.

Figure 7-7 Annual index hospitalisation rate of older adults with CHD



Index hospitalisation rate per annum for older adults (age ≥60 years) with CHD expressed as rate per 100 000 of the older adult general population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

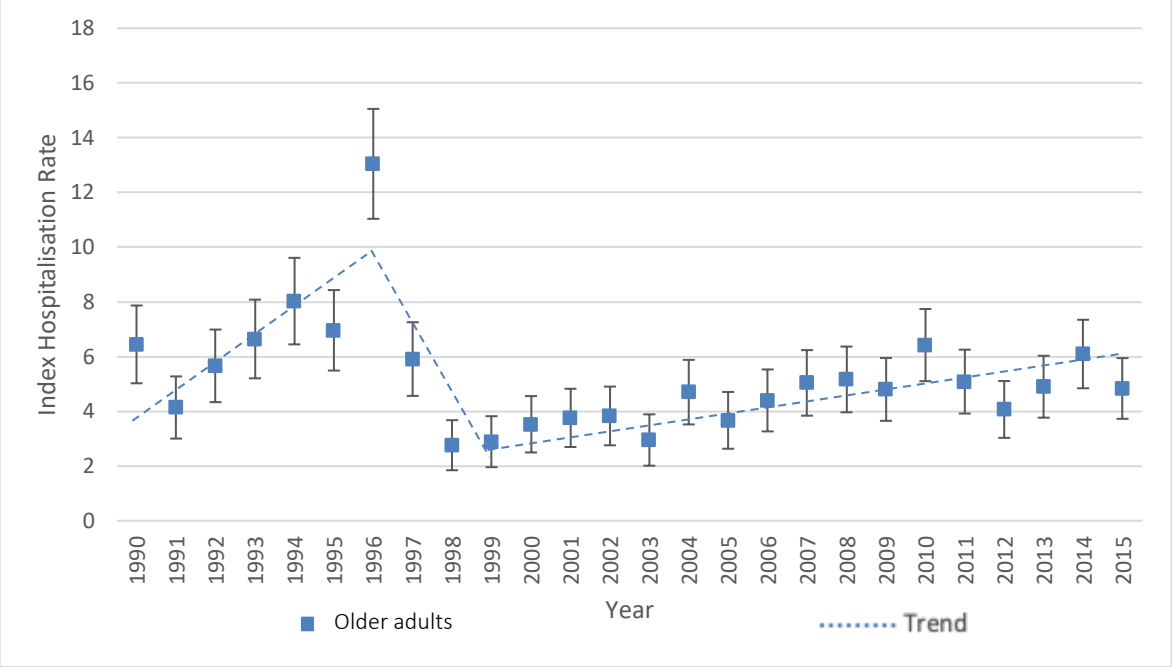
There was no change in the annual index hospitalisation rate of older adults. The APC was 1.2% (95% CI -0.2-2.7, p=0.1).

7.5.2.2 Older Adults (without diagnosis of ASD and congenital valvular lesions)

When the diagnostic and procedural coding for ASDs (and PFO) as well as valvular lesions are no longer included as CHD lesions, 1 787 individuals had an index hospitalisation with CHD during the observed years. This is 1 448 (55%) fewer index hospitalisations than was observed when ASD and valvular lesions were included. This represents 9.9% of the total hospitalisations. The index hospitalisation rate ranged from 6.4 (95% CI 5.0-7.9) in 1990 4.8 (95% CI 3.7-5.9) in 2015 per 100 000.

The index hospitalisation rate (per 100 000 of the Scottish population aged ≥60 years old) per annum is shown in Table 6, Appendix C and is displayed in Figure 7-8.

Figure 7-8 Annual index hospitalisation rate of those aged ≥60 years old with CHD, excluding ASD and congenital valvular lesions

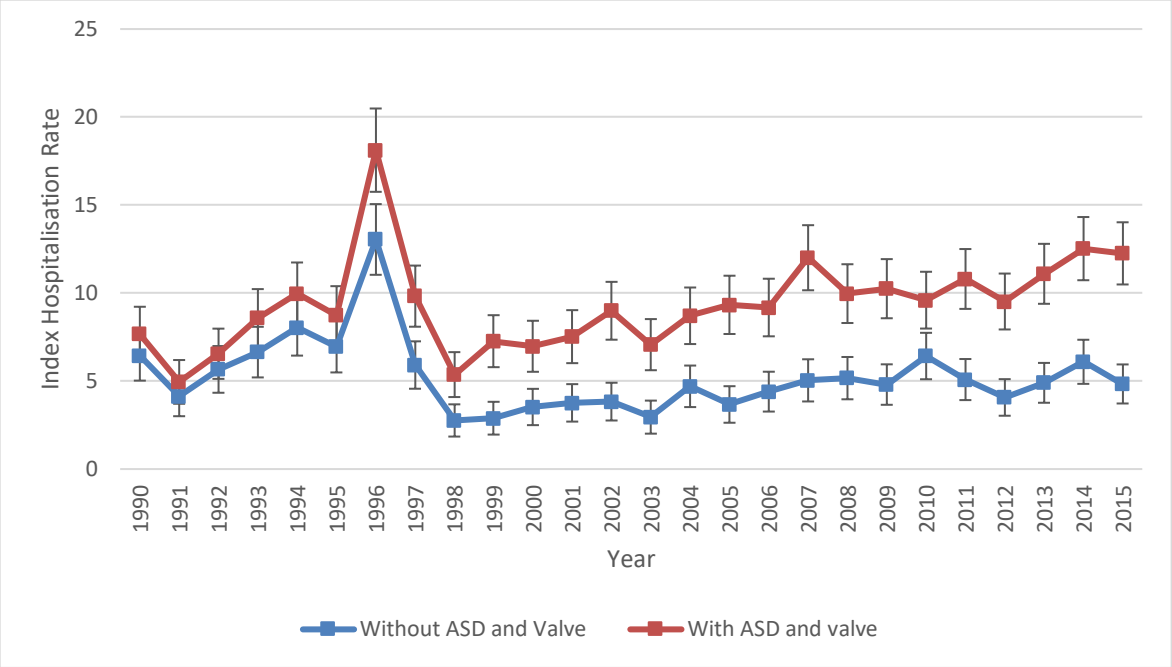


Index hospitalisation rate per annum for older adults (age≥60 years) with CHD (excluding diagnoses of ASD and congenital valvular lesions) expressed as rate per 100 000 of the older adult general population. Error bars represent 95% confidence interval. Blue dotted line represents the APC trend.

The index hospitalisation trend of older adults with ASD and valvular lesions excluded shows 2 separate joinpoints for the APC. Between 1990 and 1996 there was a 13.2% (95% CI 5.0 - 22.0%, p<0.05) annual increase in the index hospitalisation rate. Between 1996 and 1999 there was no annual change in the rate of index hospitalisation (APC -31.9%(-61.6 – 20.6%, p=0.2)) before the annual rate of index hospitalisation increased by 3.9% (95% CI 1.9 – 5.9%, p<0.05) between the years 1999 and 2015.

Figure 7-9 illustrates the annual index hospitalisation rates of those older adults (ages ≥60) with and without ASD and congenital valvular lesions. This demonstrates that although index hospitalisations are halved when those with ASD and valvular lesions are excluded, the hospitalisation rates follow a similar pattern over the observed period.

Figure 7-9 Annual index hospitalisation rate of those aged ≥60 years old with CHD, including and excluding ASD and congenital valvular lesions



Index hospitalisation rate per annum for older adults (age≥60 years) with CHD expressed as rate per 100 000 of the older adult general population. Error bars represent 95% confidence interval. The red squares represent the index hospitalisation rates of older adults with CHD including the diagnosis of ASD and valvular lesions, while the blue squares represent the index hospitalisation rates of older adults with CHD excluding the diagnoses of ASD and congenital valvular lesions.

7.6 APC Summary

Table 7-2 contains a summary of the APC in index hospitalisations with respect to underlying age. Where there were multiple joinpoints in the APC temporal trend one should refer to the corresponding figure for that cohort. A significant increase ($p<0.05$) in the APC is prefixed by a "+" and a significant decrease ($p<0.05$) in the APC is prefixed by a "-".

Table 7-2 Summary table of the APC for the studied age groupings

	Index Hospitalisations (n)	Annual Percentage Change
Infants (age <1 year)	5 838	+1.9
Children (age 1 - 15 years)	3 670	-1.5
Adults (age ≥16 years)	8 482	+3.1
Young Adults (age 20-59 years)	4 880	+4.3
Older Adults (age ≥60 years)	3 235	No change
Older Adults (age ≥60 years) Without ASD & Aortic Lesions	1 787	Multiple joinpoints

+ significant increase in APC, $p<0.05$; - significant decrease in APC, $p<0.05$

7.7 Discussion

7.7.1 Baseline Characteristics

There were significantly more paediatric patients with index hospitalisations during the study period compared to adult patients (n=9 508 and 8 482 respectively, $p<0.05$). Similar findings were reported in those articles in the literature review which included hospitalisations in all age groups.

The median age of index hospitalisation among adults in this study was 52 years. This finding is in keeping with the mean age reported by Mackie, Opotowsky and Agarwal et al.[12,44] where the median age of hospitalisation for adults in their studies was 53 and 54 respectively.

Age distribution was variable among the lesions. ASD, aortic, Ebstein's, valvular defects and other congenital lesions all had much higher levels of index hospitalisation among adults ($p<0.05$), whereas VSD, PDA, AVSD, ToF, TGA, SRV and Fontan and Complex lesions all had much higher levels of index hospitalisation among paediatric age groups ($p<0.05$). Given the natural history of the underlying pathological process in these lesion groups, they are what one would expect and also similar to what was demonstrated by Islam et al.[62]

More paediatric index hospitalisations occurred in children who reside in areas with higher levels of SED compared with adults ($p<0.05$). While this analysis has not offered an explanation for this observation, it will be discussed further in Chapter 8.

7.7.2 Infants and Children

There was a statistically significant increase in the annual infant (age <1 year) index hospitalisation rate with a diagnosis of CHD over the observed period, with an APC of 1.9% (95% CI 1.4-2.4, $p<0.050$. The increase in the index hospitalisation rate was driven by 2 factors, increasing index hospitalisations observed in the study population and a decreasing population of Scottish infants (i.e. a decreasing Scottish birth rate) between 1990 and 2015. A global study[124] assessing temporal changes in CHD incidence using the Global Health Data Exchange[125] demonstrated no change in the overall incidence of CHD between

1990 and 2015. A similar finding was concluded by Hoffman and Kaplan in a meta-analysis of 62 studies of the incidence of CHD worldwide[126]. An increase in the access and quality of pre- and neonatal diagnostic imaging techniques, including echo and CMR[127], offers one such explanation for the increase in infant CHD prevalence observed in this young population.

The index hospitalisation rate among infants (age <1) is markedly higher compared with any other age group. Infant index hospitalisation rates as high as 493.8 per 100 000 were observed, compared with 20.2 and 11.0 per 100 000 in children and adults respectively. This is likely a reflection of nearly all newborns in Scotland having an obligatory index hospitalisation at birth, creating a SMR entry and opportunity for CHD diagnostic coding (if known) and therefore a potential source of bias. In comparison, adults and children may have had a diagnosis of CHD in an outpatient setting and would not 'appear' in my analysis until they had a hospitalisation with a corresponding ICD or OPCS CHD code appearing on discharge. An infant index hospitalisation rate of 493.8 per 100 000 gives a crude CHD prevalence of 0.5% in infants. Using the infant hospitalisation numbers observed, the live birth incidence of CHD in my study is 5 per 1000, which is consistent with published rates of between 6 and 8 per 1000. [128]

The age-standardised index hospitalisation rates for infants (age<1 year) is somewhat lower compared to Billet et al.[129] in their study of CHD hospitalisations in England and Wales. Their age-standardised hospitalisation rates varied from 670 to 884 per 100 000 (from 1995 to 2004), compared to what I found, 284 to 493 per 100 000. Although the authors identified their CHD population cohort using the same methodology that I have applied, all hospitalisations were included in their study, not index hospitalisations where CHD first appears on a diagnosis list and therefore multiple hospitalisations of each patient would have contributed to the higher hospitalisation rates that they observed.

The age-standardised annual index hospitalisation rates of children (ages 1- 15 years old) decreased significantly by 1.5% (95% CI -2.1 - -0.8, $p<0.05$). This decrease may be a direct result of the higher index hospitalisation rates seen within the infant population, as described above. As more infants are diagnosed

with CHD, prenatally or in the neonatal period, then the prevalence shifts towards a younger age at diagnosis. This explanation is supported by a meta-analysis of temporal changes in paediatric prevalence of CHD carried out by Liu et al[130]. They found an increase in CHD prevalence at birth and infancy (mostly of mild severity CHD lesions) with a corresponding decrease in the first-time diagnosis of CHD in school-age children with no overall change in the overall incidence of CHD.

7.7.3 Adults

Although adult (age ≥16 years) index hospitalisation is the largest of the age groups with respect to hospitalisations (n= 8 482, 47.1% of all hospitalisations), the age-standardised index hospitalisation rate was the lowest of all the age groups. This is due to the dilutional effect of the large denominator (larger baseline age-matched population). There was a statistically significant increase in the annual index hospitalisation rate trend between 1990 and 2015, with an APC of 3.1% (95% CI 2.1-4.0, $p<0.05$). Despite the increase in the adult population of Scotland by approximately 400 000 between 1990 and 2015, the index hospitalisation rate rose as a result of the higher annual CHD index hospitalisation.

There was a 4.3% (95% CI 3.1-5.6, $p<0.05$) annual increase in the index hospitalisation rate of younger adults. Older adults (≥60) had no change in annual index hospitalisation rate (APC 1.2% (95% CI -0.2-2.7, $p=0.1$). It is worthwhile remembering that these are index hospitalisations, whereby CHD appears on a diagnosis list for the first time. There are 3 possible reasons for this:

1. First diagnosis of CHD, into adult (and in some cases elderly) life

2. Known CHD with no previous hospitalisations. Now with a cardiac hospitalisation, or unrelated non-cardiac condition and CHD mentioned in the discharge diagnosis list

3. Known CHD, with previous hospitalisation and/or cardiac interventions prior to 1990

Overall, this represents an increasing population of patients with CHD well into adulthood requiring hospitalisation for either cardiac or non-cardiac causes. This increasing trend in adult CHD hospitalisations has been well documented in the UK[76], USA[12,44,70],Europe and Asia.[131] This is in part due to factors such as improved diagnostic imaging, available medical therapies, surgical technologies and techniques as well as perioperative care. These patients are at a variably increased risk of a range of late complications, including valvular dysfunction, arrhythmia and heart failure.[132] Even if these patients have a non-cardiac hospitalisation in a secondary care environment without CHD services, they are likely to require specialist cardiology (clinicians, physiologists, nurses and other AHPs) input for interpretation of results of cardiac (and in some cases non-cardiac) investigations, as well as advice on management and perioperative care of non-cardiac surgery.

Some congenital lesions have a 'second-peak' of diagnosis in adulthood including ASD, Ebstein's, bicuspid aortic valve disease, coarctation of the aorta and ccTGA.[133] Diagnosis in later life is because of incidental findings or due to sequalae of the underlying cardiac defect. These defects over time can lead to cumulative volume-loading of the right heart or arrhythmia as seen with haemodynamically-significant ASDs, progressive ventricular and valvular dysfunction seen with bicuspid aortic valves, ccTGA and Ebstein's anomaly or secondary hypertension associated with coarctation of the aorta.[133]

Just over half (n=1 448, 55%) of all index hospitalisations in those aged ≥60 years have CHD diagnoses of ASD (or PFO) or congenital valvular lesions. The reasons for looking at this age group both including and excluding these diagnoses has been discussed in the Chapter introduction. When ASD and congenital valvular lesions are no longer included, the annual index hospitalisation rate from 1990 to 1997 fluctuates quite sharply before following a clearer trend of increasing annual index hospitalisation rates between 1998 – 2015. This is reflected by the acute change in the APC between years 1990 – 1996 and 1996 – 1999 with wide confidence intervals. The cause for this is unclear, but speculatively it may be due to the clearer definitions outlined in the change from ICD-9 to ICD-10 describing (and coding) CHD which occurred around this time in Scotland.

There is debate about whether the ICD codes for ASD (and PFO) should be included in population studies of CHD. Rodrigues et al.[134] concluded in their study of ICD coding for ASDs that a significant proportion of patients were coded incorrectly as having an ASD, when in fact patients had an alternative congenital cardiac lesion, or no CHD at all. There are faults with this study, as it was only carried in in a single adult centre, it is possible that their findings reflect their hospital's clinical coding quality rather than an endemic issue with clinical coding itself. If a diagnosis of ASD and or PFO is included in a discharge diagnosis list from a Scottish hospital, then one should assume that it was relevant to the patient's diagnosis or past medical history. Any diagnosis of ASD or PFO is likely to reflect a diagnostic trail of electrocardiogram, echocardiogram by a cardiac physiologist and consultation with a cardiologist. For that reason, until there is better quality in diagnostic coding that allows the separation of PFO and ASD as separate entities, their exclusion from population studies of CHD will underestimate the true incidence and prevalence of CHD within all patient age groups.

7.8 Conclusion

There is a rising rate of index hospitalisation among infants (age <1), adults (age ≥16) overall, as well as young adults (20-59) across the study period, with a decreasing annual hospitalisation rate among children reflecting a higher diagnosis rate of CHD being made in infancy.

The baseline characteristics in this Chapter, as well as in the previous results Chapters, has shown the clear associations in SED and CHD index hospitalisation. In the next Chapter I will explore further how CHD hospitalisation rates are affected by SED in Scotland.

8 Deprivation

8.1 Introduction

The Scottish Government's tool for analysis of SED in Scotland is SIMD. SIMD measures deprivation across more than 6 000 geographical areas (data zones) throughout Scotland with roughly equal populations in each data zone. As it is an area-based measure of relative deprivation, across several domains, not every person within a deprived area will experience the same levels of SED.

SIMD combines eight different domains to evaluate deprivation:

1. Income
2. Employment
3. Health
4. Education
5. Skills and training
6. Geographic access to services
7. Crime
8. Housing

SIMD ranks each data zone from the most deprived (SIMD1) to the least deprived (SIMD5). SIMD is updated frequently. The data used the 2012 iteration of SIMD. Previous SIMD update publications have been created in 2006 and 2009. Since the creation of the study data, a further two iterations have been implemented; 2016 and currently in use is the 2020 version.

SED in the UK has been linked with poorer health outcomes including all-cause mortality, higher hospitalisation[135] in patients with chronic heart failure[136] as well as higher prevalence of cardiovascular risk factors.[137] The association between SED and hospitalisation in CHD is less well understood and had not been described for the CHD population in Scotland.

In this Chapter I describe the association between SED and CHD hospitalisation with respect to index hospitalisation through the years 1990 – 2015 in the following groups:

- Overall hospitalisation
- Age
- CHD lesion complexity

8.2 Methods

The methods used within this chapter are outlined in Chapter 3 Methods. The age definition of infants are those patients aged <1 year, and children are those aged 1 – 15. The term paediatric refers to are all patients under the age of 16, adults are those aged ≥16. I will use quintiles to group together areas of similar SED (numbered 1 through 5), with group 1 including the 20% most deprived data zones within Scotland, and group 5 including the 20% least deprived data zones within Scotland. Index hospitalisation rates will be reported as per 100 000 of the age matched Scottish population each year.

8.3 Results

8.3.1 Baseline Characteristics

Of the 17 990 index hospitalisations, SIMD quintile rankings were available for 17 852 (99.2%). A table summarising the baseline characteristics of all individuals as well as those for in SIMD1 (most deprived) and SIMD5 (least deprived) is found in Table 8-1. The baseline characteristics for the remaining SIMD quintiles (2-4) can be found in Table 1, Appendix D.

Table 8-1 Summary of baseline characteristics for SIMD1 (most deprived) and SIMD5 (least deprived) quintiles

		SIMD Quintiles	
	All	**1 (most deprived)**	**5 (least deprived)**
Hospitalisations, n (%) [p-value]	17 852 (100)	4 852 (27.2) [<0.05]	2 818 (15.8) [<0.05]
Adults (≥16)	8 413 (47.1)	2 073 (42.7) [<0.05]	1 426 (50.6) [<0.05]
Paediatric (<16)	9 439 (52.9)	2 779 (57.3) [<0.05]	1 392 (49.4) [<0.05]
Median Age, years	25	22	28
Sex, n (%) [p-value]			
Male	8 907 (49.9)	2 307 (47.5) [<0.05]	1 445 (51.3) [<0.05]
Female	8 945 (50.1)	2 542 (52.5) [<0.05]	1 373 (48.7) [<0.05]
Lesion, n (%) [p-value]			
ASD	4 159 (23.3)	1 113 (22.9) [<0.05]	703 (24.9) [<0.05]
PDA	1 697 (9.5)	554 (11.4) [<0.05]	224 (7.9) [<0.05]
VSD	2 535 (14.2)	701 (14.4) [<0.05]	388 (13.8) [<0.05]
AVSD	863 (4.8)	233 (4.8) [<0.05]	141 (5.0) [<0.05]
Aortic	1 992 (11.1)	496 (10.2) [<0.05]	334 (11.9) [<0.05]
Ebstein's	119 (0.7)	27 (0.6) [0.46]	25 (0.9) [0.79]
ToF	774 (4.3)	213 (4.8) [<0.05]	112 (4.0) [<0.05]
TGA	220 (1.2)	54 (1.1) [0.10]	46 (1.6) [0.74]
SRV	121 (0.7)	36 (0.7) [<0.05]	17 (0.6) [0.10]
Fontan	213 (1.2)	78 (1.5) [<0.05]	33 (1.2) [0.10]
Valvular	2 054 (11.5)	495 (10.2) [<0.05]	335 (11.9) [<0.05]
Complex	1 605 (9.0)	451 (9.3) [<0.05]	228 (8.1) [<0.05]
Other	1 504 (8.4)	398 (8.2) [<0.05]	232 (8.2) [<0.05]
Lesion Complexity, n (%) [p-value]			
Mild	8 391 (47.0)	2 369 (48.8) [<0.05]	1 315 (46.7) [<0.05]
Moderate	6 022 (33.7)	1 518 (31.3) [<0.05]	993 (35.2) [<0.05]
Great	1 935 (10.8)	565 (11.6) [<0.05]	278 (9.9) [<0.05]

There is a significantly higher number of index hospitalisations associated with SIMD1 (most deprived) compared to SIMD5 (least deprived), n= 4852 and 2818 respectively ($p<0.05$), suggesting that there is an association with higher levels of SED and underlying CHD and/or CHD index hospitalisations. The remainder of this Chapter will explore this theory further.

Patients from those areas with higher levels of SED were younger at index hospitalisation compared with those of lower levels of deprivation. The median age at hospitalisation in SIMD1 (most deprived) was 22 compared to 28 in SIMD5 (least deprived).

There were significantly more females with an index hospitalisation in the most deprived (SIMD1) quintiles than compared to males, 2 542 and 2 307 respectively ($p<0.05$). There were less females with an index hospitalisation in the least deprived quintile (SIMD5) compared with males 1 373 and 1 445 respectively ($p<0.05$).

There was significant variation with regards to the prevalence of CHD lesions among the SED measures. All lesions except Ebstein's and TGA had significantly higher ($p<0.05$) index hospitalisations in SIMD1 (most deprived). Similarly, there was significantly less ($p<0.05$) index hospitalisations in SIMD 5 (least deprived) in all lesions except Ebstein's, TGA, SRV and Fontan.

8.3.2 Deprivation and All Index CHD Hospitalisations

8.3.2.1 Total Number of Index Hospitalisations Per Year

The number of index hospitalisations of patients with CHD per year 1990-2015 in each SIMD quintile is found in Table 8-2.

Table 8-2 Index hospitalisations in each SIMD quintile of per year, 1990-2015.

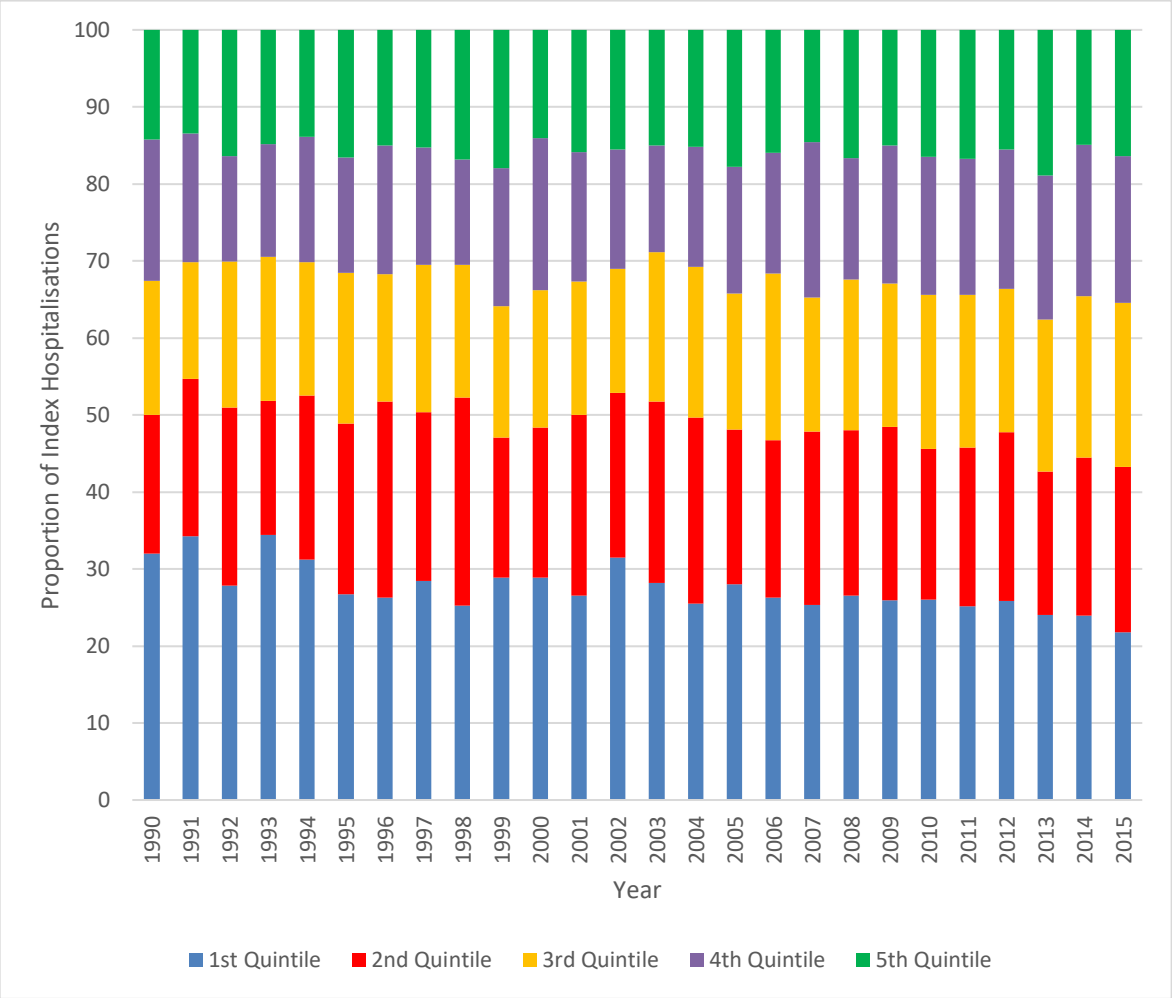
	SIMD Quintiles (%)				
Year	1	2	3	4	5
1990	173 (32)	97 (18)	94 (17)	99 (18)	77 (14)
1991	176 (34)	105 (20)	78 (15)	86 (17)	69 (13)
1992	161 (28)	134 (23)	110 (19)	79 (14)	95 (16)
1993	202 (34)	102 (27)	110 (19)	86 (15)	87 (15)
1994	184 (31)	126 (21)	102 (17)	96 (16)	82 (14)
1995	150 (27)	124 (22)	110 (20)	84 (15)	93 (17)
1996	203 (26)	197 (25)	128 (17)	129 (17)	116 (15)
1997	179 (28)	138 (22)	121 (19)	96 (15)	96 (15)
1998	144 (25)	154 (27)	98 (17)	78 (14)	96 (17)
1999	166 (29)	104 (18)	98 (17)	103 (18)	103 (18)
2000	176 (29)	119 (20)	109 (18)	120 (20)	86 (14)
2001	169 (27)	149 (23)	110 (17)	107 (17)	101 (16)
2002	210 (31)	143 (21)	108 (16)	103 (15)	104 (16)
2003	173 (28)	144 (23)	119 (19)	85 (14)	92 (15)
2004	188 (26)	178 (24)	144 (20)	115 (16)	112 (15)
2005	206 (28)	148 (20)	130 (18)	121 (16)	131 (18)
2006	206 (26)	161 (21)	170 (22)	123 (16)	125 (16)
2007	202 (25)	179 (22)	139 (17)	161 (20)	116 (15)
2008	217 (27)	176 (22)	160 (20)	129 (16)	136 (17)
2009	204 (26)	177 (22)	147 (19)	141 (18)	118 (15)
2010	207 (26)	156 (20)	159 (20)	143 (18)	131 (16)
2011	203 (25)	166 (21)	160 (20)	142 (18)	135 (17)
2012	199 (26)	169 (22)	144 (19)	139 (18)	120 (16)
2013	184 (24)	143 (19)	151 (20)	143 (19)	145 (19)
2014	192 (24)	165 (21)	168 (21)	158 (20)	120 (15)
2015	175 (22)	173 (21)	172 (21)	153 (19)	132 (16)

4 852 patients had an index hospitalisation over the study period were corresponded with SIMD1 (most deprived). This was the largest group, representing 27.2% ($p<0.05$) of all index hospitalisations. SIMD5 (least deprived) had 2 818 (15.8%, $p<0.05$) had the least number of index hospitalisations.

Each year, SIMD1 (most deprived) had the largest number of index hospitalisations with a diagnosis of CHD, except for 1998, where SIMD2 had the largest number of hospitalisations.

The proportion of patients in each SIMD with an index hospitalisation in each quintile per annum is demonstrated in the in Figure 8-1.

Figure 8-1 Proportion of patients with an index hospitalisation in each SIMD quintile



Proportion of index hospitalisations in each SIMD per annum 1990 - 2015. The blue bars represent the percentage of index hospitalisations in SIMD1 (most deprived) in each year, the red bars SIMD2 in each year, the yellow bars SIMD3 each year, the purple bars SIMD4 in each year and the green bars SIMD 5 (least deprived) each year.

8.3.2.2 Index Hospitalisation Rates (per 100 000 of the Scottish Population)

The index hospitalisations rate (per 100 000 of the Scottish population) in each SIMD quintile per year is shown in the Table 8-3.

Table 8-3 Index hospitalisation rate (100 000 of Scottish Population) of patients with CHD in each SIMD quintile per year.

	SIMD Quintiles				
Year	1 (95% CI)	2 (95% CI)	3 (95% CI)	4 (95% CI)	5 (95% CI)
1990	3.4(2.9-3.9)	1.9(1.5-2.3)	1.9(1.5-2.2)	2.0(1.56-2.3)	1.5(1.2-1.9)
1991	3.5(3.0-4.0)	2.1(1.7-2.5)	1.5(1.2-1.9)	1.7(1.33-2.1)	1.4(1.0-1.7)
1992	3.3(2.7-3.7)	2.6(2.2-3.1)	2.2(1.8-2.6)	1.6(1.21-1.9)	1.9(1.5-2.2)
1993	4.0(2.4-4.5)	2.0(1.6-2.4)	2.2(1.8-2.6)	1.7(1.33-2.1)	1.7(1.4-2.1)
1994	3.6(3.1-4.1)	2.5(2.0-2.9)	2.0(1.6-2.4)	1.9(1.51-2.3)	1.6(1.3-2.0)
1995	2.9(2.5-3.4)	2.4(2.0-2.9)	2.2(1.8-2.6)	1.7(1.29-2.0)	1.8(1.5-2.2)
1996	4.0(3.4-4.5)	3.9(3.3-4.4)	2.5(2.1-3.0)	2.5(2.10-3.0)	2.3(1.9-2.7)
1997	3.5(3.0-4.0)	2.7(2.3-3.2)	2.4(2.0-2.8)	1.9(1.51-2.3)	1.9(1.5-2.3)
1998	2.8(2.4-3.3)	3.0(2.6-3.5)	1.9(1.6-2.3)	1.5(1.20-1.9)	1.9(1.5-2.3)
1999	3.3(2.8-3.8)	2.1(1.7-2.4)	1.9(1.6-2.3)	2.0(1.64-2.4)	2.0(1.6-2.4)
2000	3.5(3.0-4.0)	2.4(1.9-2.8)	2.2(1.8-2.6)	2.4(1.95-2.8)	1.7(1.3-2.1)
2001	3.3(2.8-3.8)	2.9(2.5-3.4)	2.2(1.8-2.6)	2.1(1.71-2.5)	2.0(1.6-2.4)
2002	4.2(3.6-4.7)	2.8(2.4-3.3)	2.1(1.7-2.5)	2.0(1.64-2.4)	2.1(1.7-2.5)
2003	3.4(2.9-3.9)	2.8(2.4-3.3)	2.4(1.9-2.8)	1.7(1.32-2.0)	1.8(1.4-2)
2004	3.7(3.2-4.2)	3.5(3.0-4.0)	2.8(2.4-3.3)	2.3(1.85-2.7)	2.2(1.9-2.6)
2005	4.0(3.5-4.6)	2.9(2.4-3.4)	2.5(2.1-3.0)	2.4(1.95-2.8)	2.6(2.1-3.0)
2006	4.0(3.5-4.6)	3.1(2.7-3.6)	3.3(2.8-3.8)	2.4(1.97-2.8)	2.4(2.0-2.9)
2007	3.9(3.4-4.5)	3.5(3.0-3.9)	2.7(2.2-3.1)	3.1(2.63-3.6)	2.2(1.8-2.7)
2008	4.2(3.6-4.7)	3.4(2.9-3.9)	3.1(2.6-3.6)	2.5(2.05-2.9)	2.6(2.2-3.1)
2009	3.9(3.4-4.4)	3.4(2.9-3.9)	2.8(2.4-3.3)	2.7(2.25-3.1)	2.3(1.9-2.7)
2010	3.9(3.4-4.5)	3.0(2.5-3.4)	3.0(2.6-3.5)	2.7(2.27-3.2)	2.5(2.1-2.9)
2011	3.8(3.3-4.4)	3.1(2.7-3.6)	3.0(2.6-3.5)	2.7(2.24-3.1)	2.6(2.1-3.0)
2012	3.8(3.2-4.3)	3.2(2.7-3.7)	2.7(2.3-3.2)	2.6(2.18-3.1)	2.3(1.9-2.7)
2013	3.5(3.0-4.0)	2.7(2.2-3.1)	2.8(2.4-3.3)	2.7(2.24-3.1)	2.7(2.3-3.2)
2014	3.6(3.1-4.1)	3.1(2.6-3.6)	3.1(2.7-3.6)	2.5(2.49-3.4)	2.2(1.8-2.7)
2015	3.3(2.8-3.7)	3.2(2.7-3.7)	3.2(2.7-3.7)	2.85(2.40-3.3)	2.5(2.0-2.9)

Index hospitalisation rates for patients with CHD in SIMD1 (most deprived) ranged from 3.4 (95% CI 2.9 -3.9) in 1990 to 3.3 (95% CI 2.8-3.7) in 2015. 1996 had the highest index hospitalisation rate of 4.0 (95% CI 3.4-4.5) in the study period.

The index hospitalisation rate for patients with CHD in SIMD2 ranged from 1.9 (95% CI 1.5-2.3) in 1990 to 3.2 (95% CI 2.7-3.7) in 2015. 2008 had the highest index hospitalisation rate of 4.2 (95% CI 3.6-4.7) in the study period. SIMD2 had the 2nd largest number of index hospitalisations, representing 21.4% ($p<0.05$) of the total hospitalisations. In 1998, SIMD2 had the highest index hospitalisation rate (of that year) of 3.0 (95% CI 2.6-3.5).

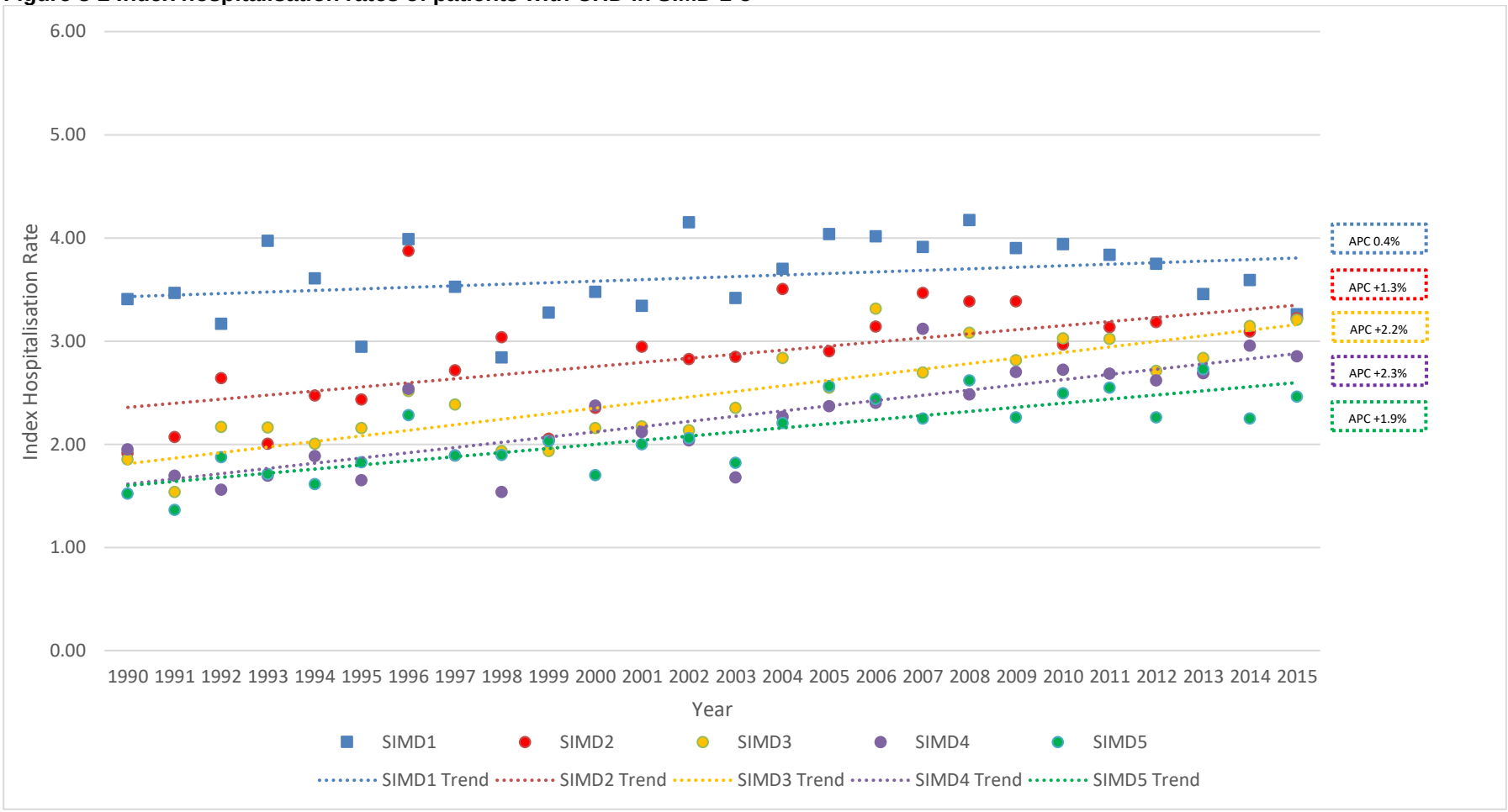
The index hospitalisation rates for patients with CHD in SIMD3 ranged from 1.9 (95% CI 1.5-2.2) in 1990 to 3.2 (95% CI 2.7-3.7) in 2015. 2006 had the highest index hospitalisation rate of 3.3(95% CI 2.8-3.8). SIMD3 had the 3rd highest index hospitalisations rate, comprising 18.7% ($p<0.05$).

The index hospitalisation rates for patients with CHD in SIMD4 ranged from 2.0 (95% CI 1.6-2.3) in 1990 to 2.9 (95% CI 2.4-3.3) in 2015. 2007 had the highest index hospitalisation rate of 3.1(95% CI 2.6-3.6). SIMD4 had the 2nd lowest index hospitalisations rate representing 16.9% ($p<0.05$).

The index hospitalisation rates for patients with CHD in SIMD5 (least deprived) ranged from 1.5 (95% CI 1.1-1.9) in 1990 to 2.5 (95% CI 2.0-2.9) in 2015. The year 2013 had the highest index hospitalisation rate of 2.7 (95% CI 2.3-3.2) in the observed period of 1990-2015. SIMD5 had the least index hospitalisations, representing 15.8% ($p<0.05$).

Figure 8-2 shows the index hospitalisation rates per year in each of the SIMD quintiles.

Figure 8-2 Index hospitalisation rates of patients with CHD in SIMD 1-5



Index hospitalisation rate per annum for all individuals with CHD in SIMD quintiles 1 (most deprived – 5 (least deprived) expressed as rate per 100 000 of the general population. The blue square represents the index hospitalisation rate in SIMD1, the red circle SIMD2, the yellow circle SIMD3, the purple circle SIMD4 and the green circle SIMD5. Blue dotted line represents the APC trend for SIMD1, the red dotted line for SIMD2, the yellow dotted line for SIMD3, the purple dotted line for SIMD4 and the green dotted line for SIMD5.

There was no change in the annual index hospitalisation rate over the study period in SIMD1. The APC was 0.4% (95% CI -0.1 – 0.9%, p=0.1). An annual increase in the index hospitalisation rates was observed in the remaining SIMD quintiles. There was a 1.3% (95% CI 0.5 – 0.9%, p<0.05) annual increase in the index hospitalisation rate in SIMD2, a 2.2% (95% CI 1.6 – 2.8%, p<0.05) increase in SIMD3, a 2.3% (95% CI 1.6 – 2.9%, p<0.05) increase in SIMD4 and a 1.9% (95% CI 1.3 – 2.5%, p<0.05) increase in SIMD5.

8.3.3 Deprivation and Age

8.3.3.1 Deprivation and Paediatric Index Hospitalisations

Between 1990 and 2015, a total of 9 508 children had an index hospitalisation to hospital with a diagnosis of CHD. Of the 9 508 hospitalised, 9 439 (99.2%) had a SIMD marker recorded (missing n=69).

The total number of children with an index hospitalisation diagnosis of CHD in each SIMD quintile is shown in the Table 8-4.

Table 8-4 Table showing index hospitalisations of patients with CHD in each SIMD quintile per annum.

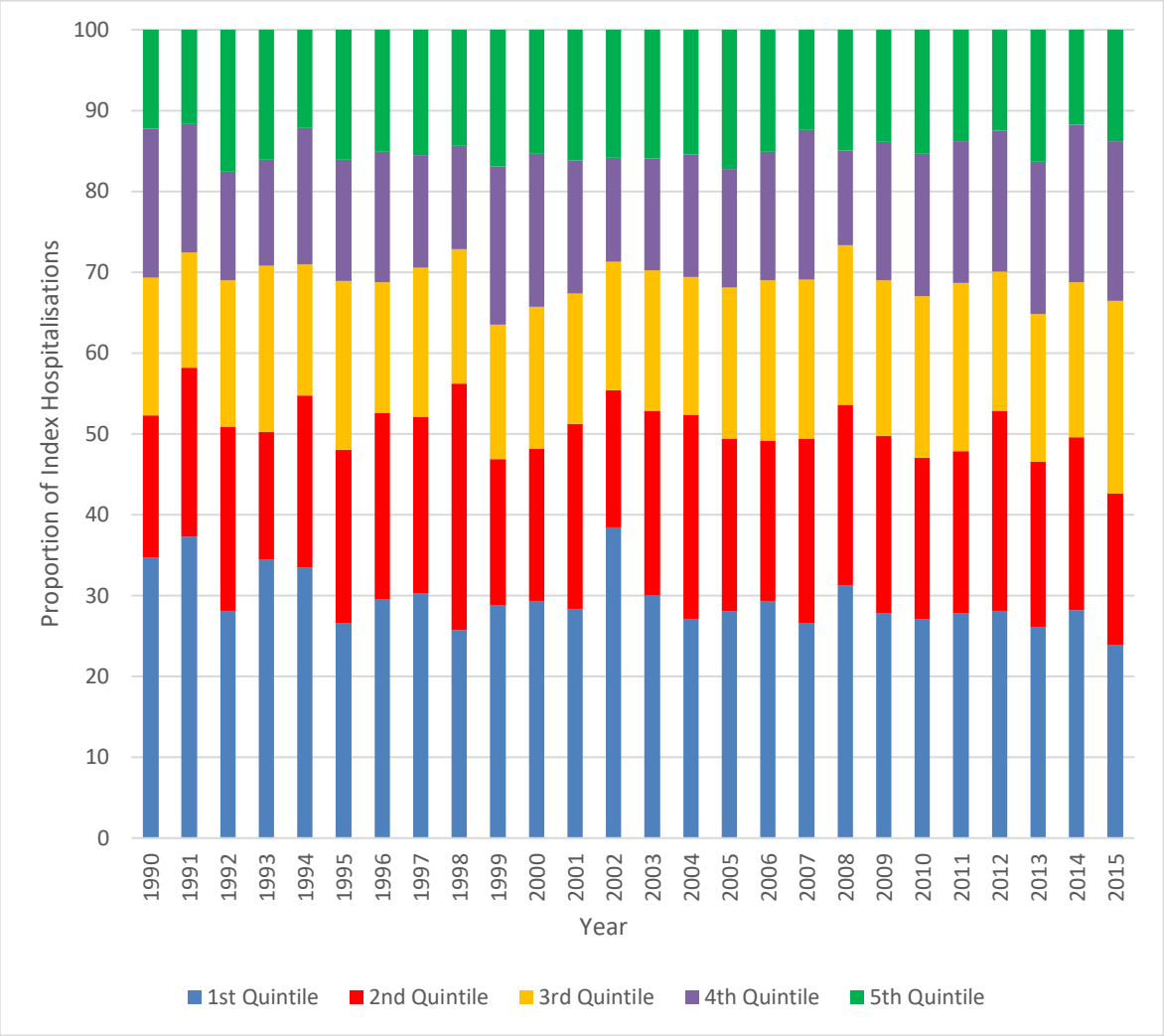
	SIMD Quintiles				
Year	**1 (%)**	**2 (%)**	**3 (%)**	**4 (%)**	**5 (%)**
1990	122 (35)	62 (18)	60 (17)	65 (18)	43 (12)
1991	134 (37)	75 (21)	51 (14)	57 (16)	42 (12)
1992	107 (28)	87 (23)	69 (18)	51 (13)	67 (18)
1993	126 (34)	58 (16)	75 (20)	48 (13)	59 (16)
1994	113 (33)	72 (21)	55 (16)	57 (17)	41 (12)
1995	89 (27)	72 (21)	70 (21)	50 (15)	54 (16)
1996	117 (29)	92 (23)	64 (16)	64 (16)	60 (15)
1997	113 (30)	82 (22)	69 (18)	52 (14)	58 (16)
1998	93 (26)	110 (30)	60 (17)	46 (13)	52 (14)
1999	97 (29)	61 (18)	56 (17)	66 (20)	57 (17)
2000	107 (29)	69 (19)	64 (18)	69 (19)	56 (15)
2001	107 (28)	86 (23)	61 (16)	62 (16)	61 (16)
2002	131 (38)	58 (17)	54 (16)	44 (13)	54 (16)
2003	100 (30)	76 (23)	58 (17)	46 (14)	53 (16)
2004	102 (27)	95 (25)	64 (17)	57 (15)	58 (15)
2005	96 (28)	73 (21)	64 (19)	50 (15)	59 (17)
2006	105 (29)	71 (20)	71 (20)	57 (16)	54 (15)
2007	96 (27)	83 (23)	71 (20)	67 (19)	45 (12)
2008	109 (31)	78 (22)	69 (20)	41 (12)	52 (15)
2009	104 (28)	82 (22)	72 (19)	64 (17)	52 (14)
2010	111 (27)	82 (20)	82 (20)	72 (18)	63 (15)
2011	111 (28)	80 (20)	83 (21)	70 (18)	55 (14)
2012	108 (28)	95 (25)	66 (17)	67 (17)	48 (13)
2013	94 (26)	74 (20)	66 (18)	68 (19)	59 (16)
2014	103 (28)	78 (21)	70 (19)	71 (19)	43 (12)
2015	81 (24)	64 (19)	81 (24)	67 (20)	47 (14)

2 779 paediatric patients with CHD had an index hospitalisation over the observed period in SIMD1 (most deprived). As a proportion, this was the largest group, comprising 29.4% ($p<0.05$) of all index hospitalisations. SIMD5 (least deprived) had 1 392(14.8%, $p<0.05$) hospitalisations and had the least index hospitalisations.

Each year, the SIMD1 (most deprived) had the largest number of index hospitalisations with a diagnosis of CHD, except for 1998, where the SIMD2 had the largest proportion of index hospitalisations, 26% and 30% respectively.

The proportion of paediatric patients with an index hospitalisation in each quintile per annum is demonstrated in the in Figure 8-3.

Figure 8-3 Proportion of index hospitalisation per year in each SIMD quintile



Proportion of index hospitalisations in each SIMD per annum 1990 - 2015. The blue bars represent the percentage of index hospitalisations in SIMD1 (most deprived) in each year, the red bars SIMD2 in each year, the yellow bars SIMD3 each year, the purple bars SIMD4 in each year and the green bars SIMD 5 (least deprived) each year.

The index hospitalisation rate (per 100 000 of the Scottish population) in each SIMD quintile, per year, is shown in the Table 8-5.

Table 8-5 Table of paediatric CHD index hospitalisation rates (100 000 of Scottish Paediatric Population) in each SIMQ quintile, per annum.

	SIMD Quintiles				
Year	1 (95% CI)	2 (95% CI)	3 (95% CI)	4 (95% CI)	5 (95% CI)
1990	12.0(9.8-14.1)	6.1(4.6-7.6)	5.9(4.4-7.4)	6.4(4.8-7.9)	4.2(3.0-5.5)
1991	13.1(10.9-15.4)	7.4(5.7-9.0)	5.0(3.6-6.4)	5.6(4.1-7.0)	4.1(2.90-5.4)
1992	10.5(8.5-12.5)	8.5(6.7-10.3)	6.8(5.2-8.3)	5.0(3.6-6.4)	6.6(5.0-8.1)
1993	12.3(10.1-14.4)	5.6(4.2-7.1)	7.3(5.7-9.0)	4.7(3.4-6.0)	5.7(4.3-7.2)
1994	10.9(8.9-13.0)	7.0(5.4-8.6)	5.3(3.9-6.7)	5.5(4.1-7.0)	4.0(2.8-5.2)
1995	8.7(6.8-10.5)	7.0(5.4-8.6)	6.8(5.2-8.4)	4.9(3.5-6.2)	5.3(3.9-6.7)
1996	11.5(9.4-13.6)	9.0(7.2-10.9)	6.3(4.7-7.8)	6.3(4.7-7.8)	5.9(4.4-7.4)
1997	11.2(9.1-13.3)	8.1(6.3-9.9)	6.8(5.2-8.4)	5.2(3.8-6.6)	5.7(4.3-7.2)
1998	9.3(7.4-11.2)	11.0(8.9-13.0)	6.0(4.5-7.5)	4.6(3.3-5.9)	5.2(3.8-6.6)
1999	9.7(7.8-11.7)	6.1(4.6-7.7)	5.6(4.2-7.1)	6.6(5.0-8.2)	5.7(4.2-7.2)
2000	10.9(8.8-13.0)	7.0(5.3-8.7)	6.5(4.9-8.1)	7.0(5.4-8.7)	5.7(4.2-7.2)
2001	11.0(8.9-13.1)	8.9(7.0-10.8)	6.3(4.7-7.9)	6.4(4.8-8.0)	6.3(4.7-7.9)
2002	13.7(11.3-16.0)	6.1(4.5-7.6)	5.6(4.1-7.1)	4.6(3.2-6.0)	5.6(4.1-7.1)
2003	10.6(8.5-12.7)	8.0(6.2-9.9)	6.1(4.6-7.7)	4.9(3.5-6.3)	5.6(4.1-7.1)
2004	10.9(8.7-13.0)	10.1(8.1-12.2)	6.8(5.2-8.5)	6.1(4.5-7.7)	6.2(4.6-7.8)
2005	10.3(8.2-12.4)	7.8(6.0-9.7)	6.9(5.2-8.6)	5.4(3.9-6.9)	6.3(4.7-8.0)
2006	11.3(9.2-13.5)	7.7(5.9-9.5)	7.7(5.9-9.5)	6.2(4.6-7.8)	5.8(4.3-7.4)
2007	10.4(8.3-12.5)	9.0(7.0-10.9)	7.7(5.9-8.5)	7.3(5.5-9.0)	4.9(3.5-6.3)
2008	11.8(9.6-14.1)	8.5(6.6-10.4)	7.5(5.7-9.3)	4.5(3.1-5.8)	5.6(4.1-7.2)
2009	11.3(9.1-13.5)	8.9(7.0-10.9)	7.8(6.0-9.6)	7.0(5.3-8.7)	5.7(4.1-7.2)
2010	12.1(9.8-14.4)	8.9(7.0-10.7)	8.9(7.0-10.9)	7.8(6.0-9.7)	6.9(5.18-8.6)
2011	12.1(9.8-14.4)	8.7(6.8-12.5)	9.1(7.1-11.0)	7.6(5.9-9.4)	6.0(4.4-7.6)
2012	11.8(9.6-14.1)	10.4(8.3-10.0)	7.2(5.5-9.0)	7.3(5.6-9.1)	5.3(3.8-6.7)
2013	10.3(8.2-12.4)	8.1(6.3-10.5)	7.2(5.5-9.0)	7.5(5.7-9.2)	6.5(4.8-8.1)
2014	11.3(9.1-13.5)	8.6(6.6-8.8)	7.7(5.9-9.5)	7.8(6.0-9.6)	4.7(3.3-6.1)
2015	8.9(6.9-10.8)	7.0(5.3-8.8)	8.9(7.0-10.8)	7.3(6.0-9.1)	5.2(3.7-6.6)

The index hospitalisation rate for paediatric patients with CHD in SIMD1 (most deprived) ranged from 11.9 (95% CI 9.8–14.1) in 1990 to 8.8 (95% CI 6.9-10.8) in 2015. 2002 had the highest index hospitalisation rate of 13.7 (95% CI 11.3-16.0). Each year, SIMD1 had the highest proportion of index hospitalisations compared to other quintiles, except in 1998 where SIMD2 had the highest proportion of index hospitalisations.

The index hospitalisation rate for paediatric patients with CHD in SIMD2 (2nd most deprived) ranged from 6.1 (95% CI 4.6-7.6) in 1990 to 7.0 (95% CI 5.3-8.8) in 2015. 1998 had the highest index hospitalisation rate of 11.0 (95% CI 8.9-13.0). SIMD2 had the 2nd highest index hospitalisations, 21.4% ($p<0.05$) total paediatric hospitalisations. In 1998, SIMD2 had the highest index hospitalisation rate (of that year) of 11.0 (95% CI 8.9-13.0).

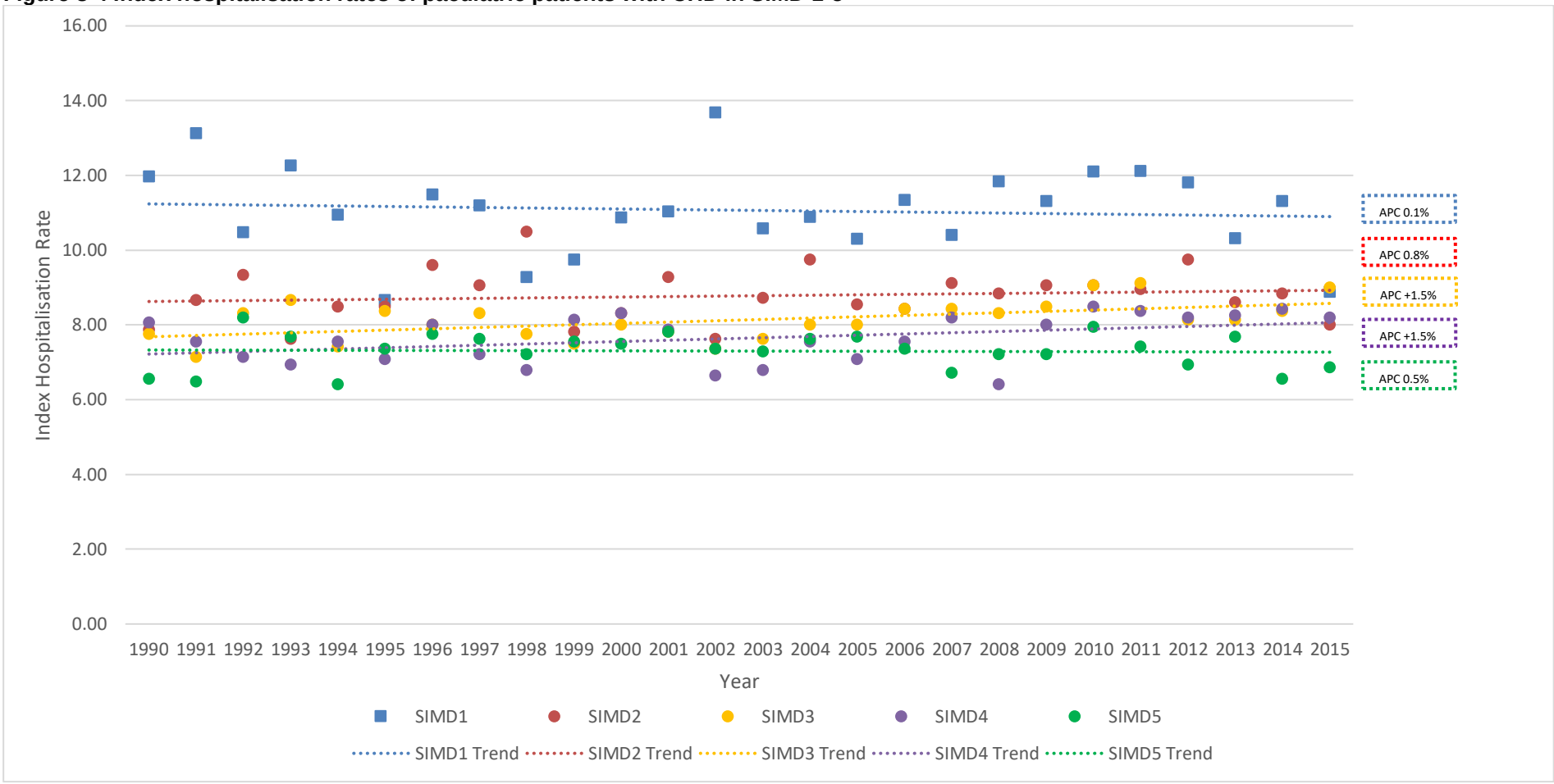
The index hospitalisation rate for paediatric patients with CHD in SIMD3 ranged from 5.9 (95% CI 4.4-7.4) in 1990 to 8.9 (95% CI 7.0-10.8) in 2015. 2011 had the highest index hospitalisation rate of 9.1 (95% CI 7.1-11.0). SIMD3 had the 3rd highest hospitalisations, 18.3% ($p<0.05$) total paediatric index hospitalisations.

The index hospitalisation rate for paediatric patients with CHD in SIMD4 (2nd least deprived) ranged from 6.4 (95% CI 4.8–7.9) in 1990 to 7.3 (95% CI 5.6–9.1) in 2015. 2010 had the highest index hospitalisation rate of 7.8 (95% CI 6.0– 9.7). The 4th SIMD quintile had the 4th highest number of index hospitalisations, representing 16.2% ($p<0.05$).

The index hospitalisation rate for paediatric patients with CHD in SIMD5 (least deprived) ranged from 4.2 (95% CI 3.0–5.5) in 1990 to 5.2 (95% CI 3.7–6.6) in 2015. 2010 had the highest index hospitalisation rate in of 6.9 (95% CI 5.2– 8.6). SIMD5 had the 5th highest number of index hospitalisations, representing 14.8% ($p<0.05$).

Figure 8-4 shows the index hospitalisation rates per year in each of the SIMD quintiles for paediatric patients.

Figure 8-4 Index hospitalisation rates of paediatric patients with CHD in SIMD 1-5



Index hospitalisation rate per annum for paediatric individuals with CHD in SIMD quintiles 1 (most deprived – 5 (least deprived) expressed as rate per 100 000 of the paediatric population. The blue square represents the index hospitalisation rate in SIMD1, the red circle SIMD2, the yellow circle SIMD3, the purple circle SIMD4 and the green circle SIMD5. Blue dotted line represents the APC trend for SIMD1, the red dotted line for SIMD2, the yellow dotted line for SIMD3, the purple dotted line for SIMD4 and the green dotted line for SIMD5

There was no change in the annual index hospitalisation rate of paediatric SIMD1 and SIMD2 over the study period, the APC was 0.1% (95% CI -0.7 – 0.4%, p=0.6) and 0.8% (95% CI -0.1 – 1.7%, p=0.6) respectively. There was a 1.5% (95% CI 0.9 – 2.1%, p<0.05) and 1.5% (95% CI 0.7 – 2.3%, p<0.05) annual increase in the index hospitalisation rate in paediatric SIMD3 and SIMD4 respectively. There was no change in the annual index hospitalisation rate of paediatric SIMD5 over the study period, the APC was 0.5% (95% CI -0.2 – 1.2%, p=0.2).

8.3.3.2 Deprivation and Adult Index Hospitalisations

Between the years 1990 and 2015, 8 842 adults had an index hospitalisation with a diagnosis of CHD. Of these, 8 413 (99.2%) had a SIMD marker recorded (missing n=69).

Over the observed period, SIMD1 (most deprived) had the largest proportion of index hospitalisations, 2 073 (24.6%, p<0.05) with the 5th SIMD quintile (least deprived) having the fewest number of index hospitalisations, 1 426 (16.8%, p<0.05).

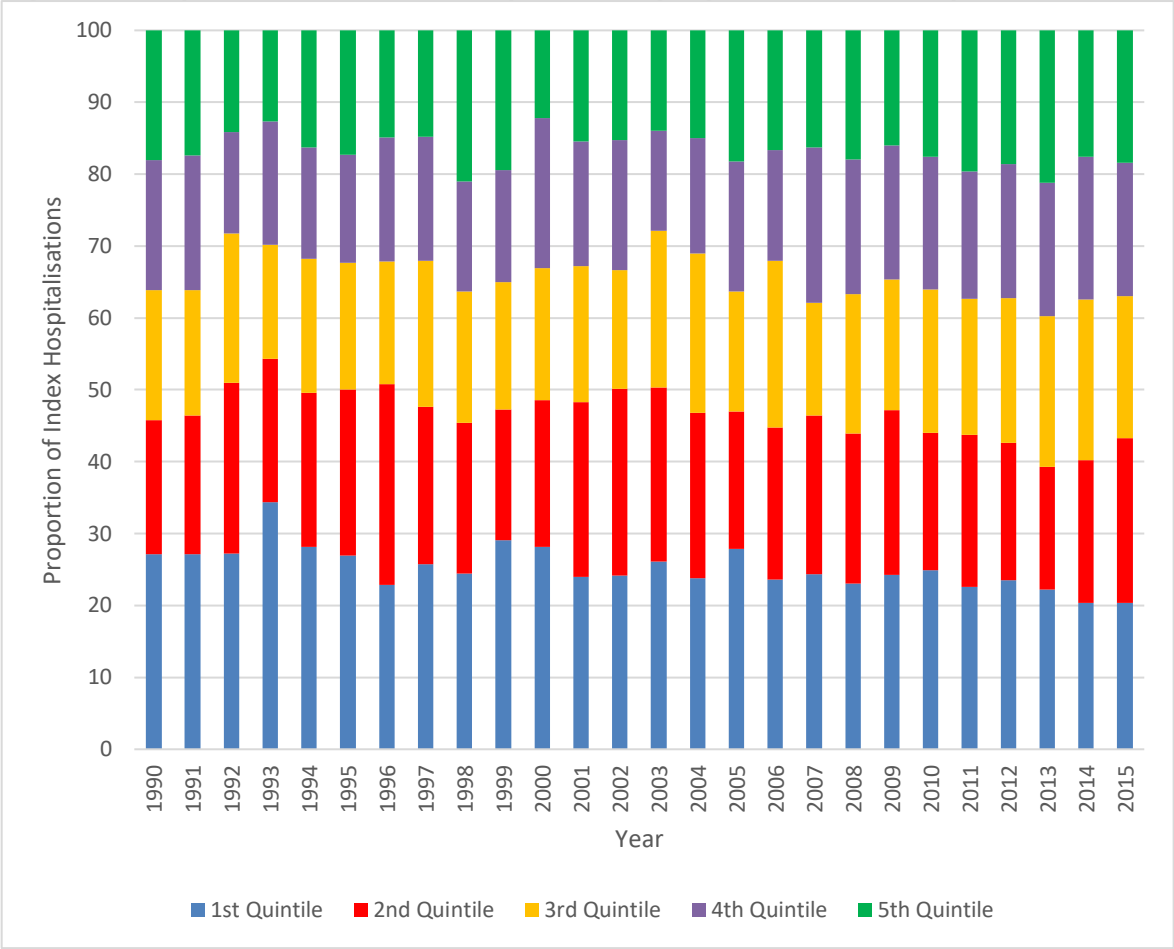
The total number of adults with an index hospitalisation with CHD in each SIMD quintile is shown in the Table 8-6.

Table 8-6 Number of adult index hospitalisations with CHD in each SIMD quintile per annum, 1990 – 2015.

	SIMD Quintiles				
Year	**1 (%)**	**2 (%)**	**3 (%)**	**4 (%)**	**5 (%)**
1990	51(27)	35(19)	34(18)	34(18)	34(18)
1991	42(27)	30(19)	27(17)	29(19)	27(17)
1992	54(27)	47(24)	41(21)	28(14)	28(14)
1993	76(34)	44(20)	35(16)	38(17)	28(13)
1994	71(28)	54(21)	47(19)	39(15)	41(16)
1995	61(27)	52(23)	40(18)	34(15)	39(17)
1996	86(23)	105(28)	64(17)	65(17)	56(15)
1997	66(26)	56(22)	52(20)	44(17)	38(15)
1998	51(24)	44(21)	38(18)	32(15)	44(21)
1999	69(29)	43(18)	42(18)	37(16)	46(19)
2000	69(28)	50(20)	45(18)	51(21)	30(12)
2001	62(24)	63(24)	49(19)	45(17)	40(15)
2002	79(24)	85(26)	54(17)	59(18)	50(15)
2003	73(26)	68(24)	61(22)	39(14)	39(14)
2004	86(24)	83(23)	80(22)	58(16)	54(15)
2005	110(28)	75(19)	66(17)	71(18)	72(18)
2006	101(24)	90(21)	99(23)	66(15)	71(17)
2007	106(24)	96(22)	68(16)	94(22)	71(16)
2008	108(23)	98(21)	91(19)	88(19)	84(18)
2009	100(24)	95(23)	75(18)	77(19)	66(16)
2010	96(25)	74(19)	77(20)	71(18)	68(18)
2011	92(23)	86(21)	77(19)	72(18)	80(20)
2012	91(24)	74(19)	78(20)	72(19)	72(19)
2013	90(22)	69(17)	85(21)	75(19)	86(21)
2014	89(20)	87(20)	98(22)	87(20)	77(18)
2015	94(20)	106(23)	91(20)	86(19)	85(18)

Each year, the SIMD1 (most deprived) had the largest number of index hospitalisations with a diagnosis of CHD, except 1996, 2001-02 and 2015, where SIMD2 had the largest proportion of hospitalisations. The proportion of adult patients with an index hospitalisation in each quintile, per annum, is demonstrated in Figure 8-5.

Figure 8-5 Proportion of adult index hospitalisation per year in each SIMD quintile



Proportion of index hospitalisations in each SIMD per annum 1990 - 2015. The blue bars represent the percentage of index hospitalisations in SIMD1 (most deprived) in each year, the red bars SIMD2 in each year, the yellow bars SIMD3 each year, the purple bars SIMD4 in each year and the green bars SIMD 5 (least deprived) each year.

The index hospitalisation rates for adult patients with CHD in Scotland per 100 000 of the Scottish adult population can be found in Table 8-7.

Table 8-7 Adult index hospitalisations rates of patients with CHD in Scotland (100 000 of the Scottish adult population (95% CI)

	SIMD Quintiles				
Year	**1 (95% CI)**	**2 (95% CI)**	**3 (95% CI)**	**4 (95% CI)**	**5 (95% CI)**
1990	1.3(0.9-1.6)	0.9(0.6-1.6)	0.8(0.6-1.1)	0.8(0.6-1.1)	0.8(0.6-1.1)
1991	1.0(0.7-1.7)	0.7(0.5-1.0)	0.7(0.4-0.9)	0.7(0.5-1.0)	0.7(0.4-0.9)
1992	1.3(1.0-1.7)	1.2(0.8-1.5)	1.0(0.7-1.3)	0.7(0.4-0.9)	0.7(0.4-0.9)
1993	1.9(1.5-2.3)	1.1(0.8-1.4)	0.9(0.6-1.2)	0.9(0.6-1.2)	0.7(0.4-0.9)
1994	1.7(1.3-2.2)	1.3(1.0-1.7)	1.2(0.8-1.5)	1.0(0.7-1.3)	1.0(0.7-1.3)
1995	1.5(1.1-1.9)	1.3(0.9-1.6)	1.0(0.7-1.3)	0.8(0.6-1.1)	1.0(0.7-1.3)
1996	2.1(1.7-2.6)	2.6(2.1-3.1)	1.6(1.2-2.0)	1.6(1.2-2.0)	1.4(1.0-1.7)
1997	1.6(1.2-2.0)	1.4(1.0-1.7)	1.3(0.9-1.6)	1.1(0.8-1.4)	0.9(0.6-1.2)
1998	1.3(0.9-1.6)	1.1(1.8-1.4)	0.9(0.6-1.2)	0.8(0.5-1.1)	1.1(0.8-1.4)
1999	1.7(1.3-2.1)	1.1(0.7-1.4)	1.0(0.7-1.3)	0.9(0.6-1.2)	1.1(0.8-1.5)
2000	1.7(1.3-2.1)	1.2(0.9-1.6)	1.1(0.8-1.4)	1.3(0.9-1.6)	0.7(0.5-1.0)
2001	1.5(1.1-1.9)	1.5(1.2-1.9)	1.2(0.9-1.5)	1.1(0.8-1.4)	1.0(0.7-1.3)
2002	1.9(1.5-2.4)	2.1(1.6-2.5)	1.3(0.9-1.7)	1.4(1.1-1.8)	1.2(0.9-1.6)
2003	1.8(1.4-2.2)	1.7(1.3-2.0)	1.5(1.1-1.9)	1.0(0.7-1.2)	1.0(0.7-1.2)
2004	2.1(1.6-2.5)	2.0(1.6-2.4)	1.9(1.5-2.4)	1.4(1.0-1.8)	1.3(1.0-1.7)
2005	2.6(2.1-3.1)	1.8(1.4-2.2)	1.6(1.2-2.0)	1.7(1.3-2.1)	1.7(1.3-2.1)
2006	2.4(1.9-2.9)	2.1(1.7-2.6)	2.4(1.9-2.8)	1.6(1.2-2.0)	1.7(1.3-2.1)
2007	2.5(2.0-3.0)	2.3(1.8-2.7)	1.6(1.2-2.0)	2.2(1.8-2.7)	1.7(1.3-2.1)
2008	2.5(2.1-3.0)	2.3(1.8-2.7)	2.1(1.7-2.6)	2.1(1.6-2.5)	2.0(1.5-2.4)
2009	2.3(1.9-2.8)	2.2(1.8-2.7)	1.7(1.4-2.1)	1.8(1.4-2.2)	1.5(1.2-1.9)
2010	2.2(1.8-2.7)	1.7(1.3-2.1)	1.8(1.4-2.2)	1.6(1.3-2.0)	1.6(1.2-1.9)
2011	2.1(1.7-2.5)	2.0(1.6-2.4)	1.8(1.4-2.2)	1.6(1.3-2.0)	1.8(1.4-2.2)
2012	2.1(1.6-2.5)	1.7(1.3-2.1)	1.8(1.4-2.2)	1.6(1.3-2.0)	1.6(1.2-2.0)
2013	2.0(1.6-2.5)	1.6(1.2-1.9)	1.9(1.5-2.3)	1.7(1.3-2.1)	2.0(1.5-2.4)
2014	2.0(1.6-2.4)	2.0(1.6-2.4)	2.2(1.8-2.7)	2.0(1.6-2.4)	1.7(1.4-2.1)
2015	2.1(1.7-2.5)	2.4(1.9-2.8)	2.0(1.6-2.5)	1.9(1.5-2.3)	1.9(1.5-2.3)

The index hospitalisation rate for adult patients with CHD in the 1st quintile (most deprived) ranged from 1.3 (95% CI 0.9-1.6) in 1990 to 2.1 (95% CI 1.7-2.5) in 2015. 2005 had the highest index hospitalisation rate of 2.6 (95% CI 2.1-3.1). Each year, the 1st SIMD quintile had the highest index hospitalisation rates compared to other quintiles, except in the years 1996, 2001-02 & 2015 where the 2nd quintile had the highest index hospitalisation rates. The 1st adult quintile comprised 24.6% ($p<0.05$) of the total adult index hospitalisations.

The index hospitalisation rate for adult patients with CHD in the 2nd quintile (2nd most deprived) ranged from 0.9 (95% CI 0.6-1.2) in 1990 to 2.4 (95% CI 1.9-2.8) in 2015. 1996 had the highest index hospitalisation rate of 2.6 (95% CI 2.1-3.1). The 2nd SIMD quintile had the 2nd highest index hospitalisation comprising 21.5% ($p<0.05$) of the total hospitalisations.

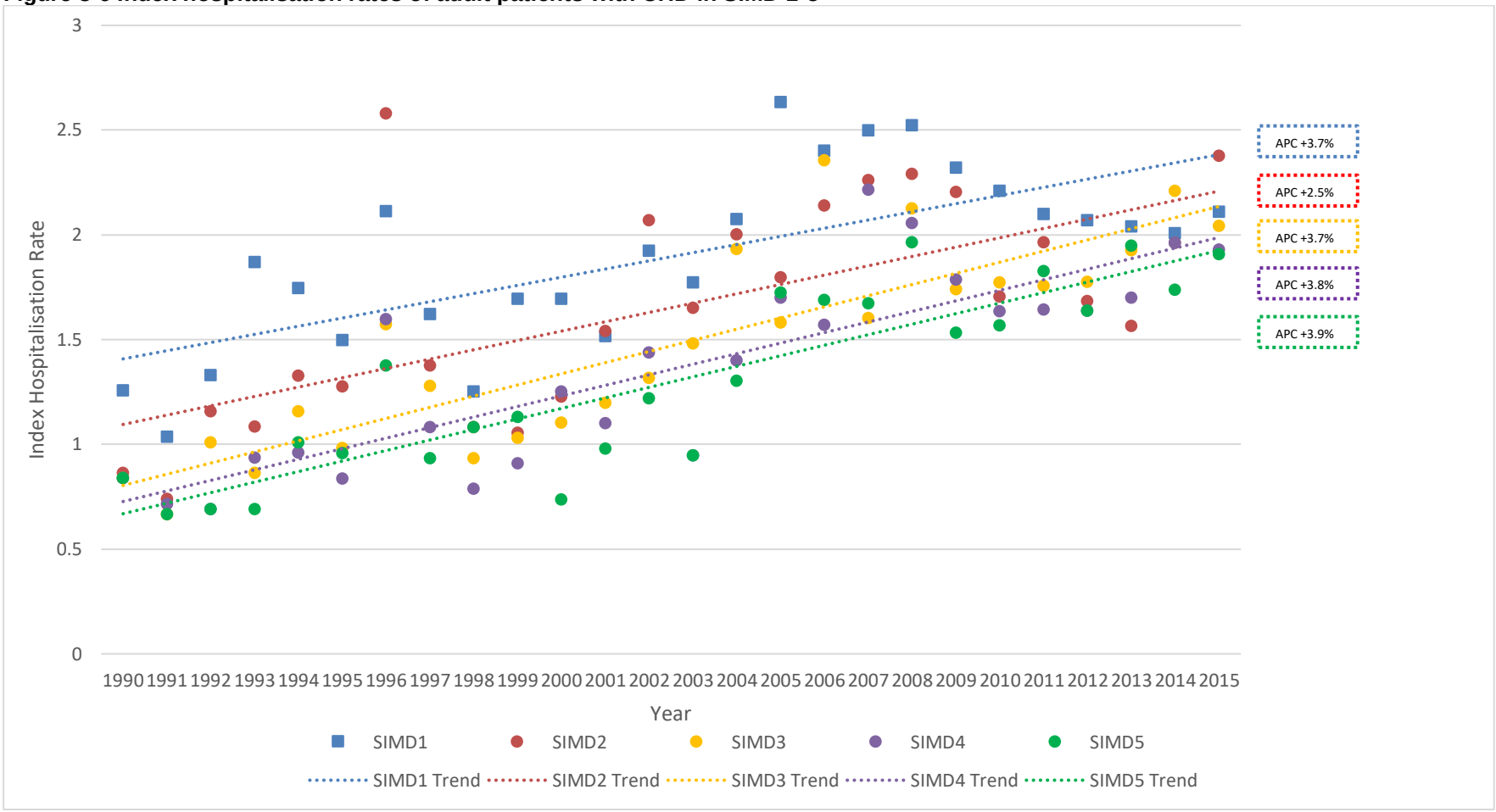
The index hospitalisation rate for adult patients with CHD in the 3rd quintile ranged from 0.8 (95% CI 0.6-1.1) in 1990 to 2.0 (95% CI 1.6-2.5) in 2015. 2006 had the highest index hospitalisation rate of 2.4 (95% CI 1.9-2.8). The 3rd SIMD quintile had the 3rd highest index hospitalisations, representing 19.2% of total index hospitalisations.

The index hospitalisation rate for adult patients with CHD in the 4th quintile (2nd least deprived) ranged from 0.8 (95% CI 0.6-1.1) in 1990 to 1.9 (95% CI 1.3-2.3) in 2015. 2007 had the highest index hospitalisation rate of 2.2 (95% CI 1.8-2.7). The 4th SIMD quintile had the 2nd fewest index hospitalisations comprising 17.7% ($p<0.05$) of the total observed.

The index hospitalisation rate for adult patients with CHD in the 5th quintile (least deprived) ranged from 0.8 (95% CI 0.6-1.1) in 1990 to 1.9 (95% CI 1.5-2.3) in 2015. 2008 saw the highest index hospitalisation rate of 2.0 (95% CI 1.5-2.4). The 5th SIMD quintile had the least index hospitalisations, representing 16.8% ($p<0.05$) of the total observed.

Figure 8-6 shows the index hospitalisation rates per year in each of the SIMD quintiles for adult patients.

Figure 8-6 Index hospitalisation rates of adult patients with CHD in SIMD 1-5



Index hospitalisation rate per annum for adult individuals with CHD in SIMD quintiles 1 (most deprived – 5 (least deprived) expressed as rate per 100 000 of the adult population. The blue square represents the index hospitalisation rate in SIMD1, the red circle SIMD2, the yellow circle SIMD3, the purple circle SIMD4 and the green circle SIMD5. Blue dotted line represents the APC trend for SIMD1, the red dotted line for SIMD2, the yellow dotted line for SIMD3, the purple dotted line for SIMD4 and the green dotted line for SIMD5.

There was a significant increase in the annual index hospitalisation rate for each SIMD quintile. There was a 3.7% (95%CI 2.1 – 5.2%, p<0.05) annual increase in SIMD1, a 2.5% (95%CI 1.1 – 4.0%), p<0.05) annual increase in SIMD2, a 3.7% (95%CI 2.6 – 4.7%, p<0.05) annual increase in SIMD3, a 3.8% (95% CI 2.6 – 4.9%, p<0.05) annual increase in SIMD4 and a 3.9% (95% CI 2.6 – 4.9%, p<0.05) annual increase in SIMD5

8.3.4 Lesion Complexity and Deprivation

As described previously, CHD lesions can be grouped together depending on the physiological complexity of the underlying congenital cardiac lesion. They are grouped together in lesions of mild, moderate and great complexity.

8.3.4.1 Mild Lesion Complexity and Deprivation

The index hospitalisation rates for individuals with CHD lesions of mild complexity, per 100 000 of the Scottish population can be found in Table 8-8.

Table 8-8 Index hospitalisations rate of patients with lesions of mild complexity in Scotland (per 100 000 of the Scottish population)

	SIMD Quintiles				
Year	**1 (95% CI)**	**2 (95% CI)**	**3 (95% CI)**	**4 (95% CI)**	**5 (95% CI)**
1990	1.5(1.2-1.8)	0.9(0.6-1.2)	0.8(0.5-1.0)	0.8(0.6-1.1)	0.6(0.4-0.8)
1991	1.3(1.0-1.6)	0.8(0.6-1.1)	0.7(0.4-0.9)	0.6(0.4-0.8)	0.5(0.3-0.7)
1992	1.4(1.1-1.7)	1.2(0.9-1.5)	1.0(0.8-1.3)	0.7(0.4-0.9)	0.7(0.5-1.0)
1993	1.8(1.5-2.2)	0.8(0.6-1.1)	1.0(0.7-1.3)	0.6(0.4-0.9)	0.8(0.5-1.0)
1994	1.5(1.2-1.9)	1.0(0.7-1.3)	0.9(0.7-1.2)	0.8(0.6-1.1)	0.8(0.6-1.0)
1995	1.2(0.9-1.5)	0.9(0.6-1.1)	1.1(0.8-1.4)	0.6(0.4-0.8)	0.8(0.6-1.1)
1996	1.7(1.3-2.1)	1.2(0.9-1.5)	0.7(0.5-1.0)	0.9(0.6-1.2)	0.8(0.6-1.1)
1997	1.5(1.1-1.8)	0.9(0.6-1.2)	0.6(0.4-0.8)	0.6(0.4-0.8)	0.8(0.6-1.1)
1998	1.4(1.1-1.7)	1.2(0.9-1.5)	0.8(0.6-1.1)	0.7(0.5-1.0)	1.0(0.7-1.3)
1999	1.3(1.0-1.7)	0.8(0.6-1.1)	0.7(0.4-0.9)	0.8(0.6-1.1)	0.8(0.6-1.1)
2000	1.5(1.2-1.9)	0.9(0.7-1.2)	0.9(0.6-1.1)	1.0(0.8-1.3)	0.6(0.4-0.8)
2001	1.5(1.1-1.8)	1.5(1.1-1.8)	1.0(0.7-1.3)	0.7(0.5-0.9)	0.7(0.5-1.0)
2002	2.4(2.0-2.8)	1.5(1.1-1.8)	1.0(0.7-1.3)	1.2(0.9-1.5)	0.9(0.6-1.2)
2003	1.8(1.4-2.1)	1.4(1.1-1.7)	1.2(0.9-1.5)	0.9(0.6-1.2)	0.9(0.6-1.2)
2004	2.3(1.8-2.7)	1.8(1.4-2.1)	1.5(1.2-1.9)	1.0(0.7-1.3)	0.9(0.7-1.2)
2005	2.3(1.9-2.7)	1.4(1.1-1.8)	1.1(0.8-1.3)	1.4(1.0-1.7)	1.4(1.1-1.7)
2006	2.3(1.9-2.7)	1.9(1.5-2.2)	1.7(1.4-2.1)	1.3(1.0-1.7)	1.6(1.3-2.0)
2007	2.2(1.8-2.6)	2.1(1.7-2.5)	1.3(1.0-1.6)	1.6(1.3-2.0)	1.1(0.8-1.4)
2008	2.4(2.0-2.8)	2.0(1.6-2.3)	1.6(1.3-1.9)	1.3(1.0-1.6)	1.5(1.1-1.8)
2009	2.1(1.7-2.5)	1.8(1.5-1.2)	1.5(1.2-1.8)	1.4(1.1-1.7)	1.2(0.9-1.5)
2010	2.0(1.6-2.4)	1.5(1.2-1.9)	1.5(1.2-1.9)	1.5(1.2-1.9)	1.2(0.9-1.5)
2011	1.7(1.4-2.1)	1.5(1.2-1.9)	1.2(0.9-1.5)	1.3(1.0-1.6)	1.2(0.9-1.5)
2012	1.9(1.5-2.3)	1.4(1.1-1.7)	1.4(1.1-1.7)	1.3(1.0-1.6)	1.1(0.8-1.3)
2013	1.7(1.3-2.0)	1.2(0.9-1.5)	1.3(1.0-1.6)	1.3(1.0-1.6)	1.3(1.0-1.6)
2014	1.7(1.4-2.1)	1.6(1.3-1.9)	1.4(1.1-1.7)	1.3(1.0-1.6)	1.1(0.9-1.4)
2015	1.5(1.2-1.8)	1.4(1.1-1.8)	1.2(0.9-1.4)	1.1(0.9-1.4)	1.0(0.8-1.3)

Index hospitalisation rates for patients with mild CHD lesion complexity CHD in the 1st quintile (most deprived) ranged from 1.5 (95% CI 1.2-1.8) in 1990 to 1.5 (95% CI 1.2-1.8) in 2015. 2002 and 2008 had the highest index hospitalisation rate of 2.4 (95% CI 2.0-2.8). The 1st SIMD quintile had the largest number of index hospitalisations of lesions of mild complexity comprising 28.2% ($p<0.05$) of the total mild lesion index hospitalisations.

Index hospitalisation rates for patients with mild CHD lesion complexity CHD in the 2nd quintile (2nd most deprived) ranged from 0.9 (95% CI 0.6-1.2) in 1990 to 1.4 (95% CI 1.1-1.8) in 2015. 2007 had the highest index hospitalisation rate of 2.4 (95% CI 1.7-2.5). The 2nd SIMD quintile had the 2nd highest index hospitalisations of lesions of mild complexity comprising of 21.4% the total mild lesion index hospitalisations.

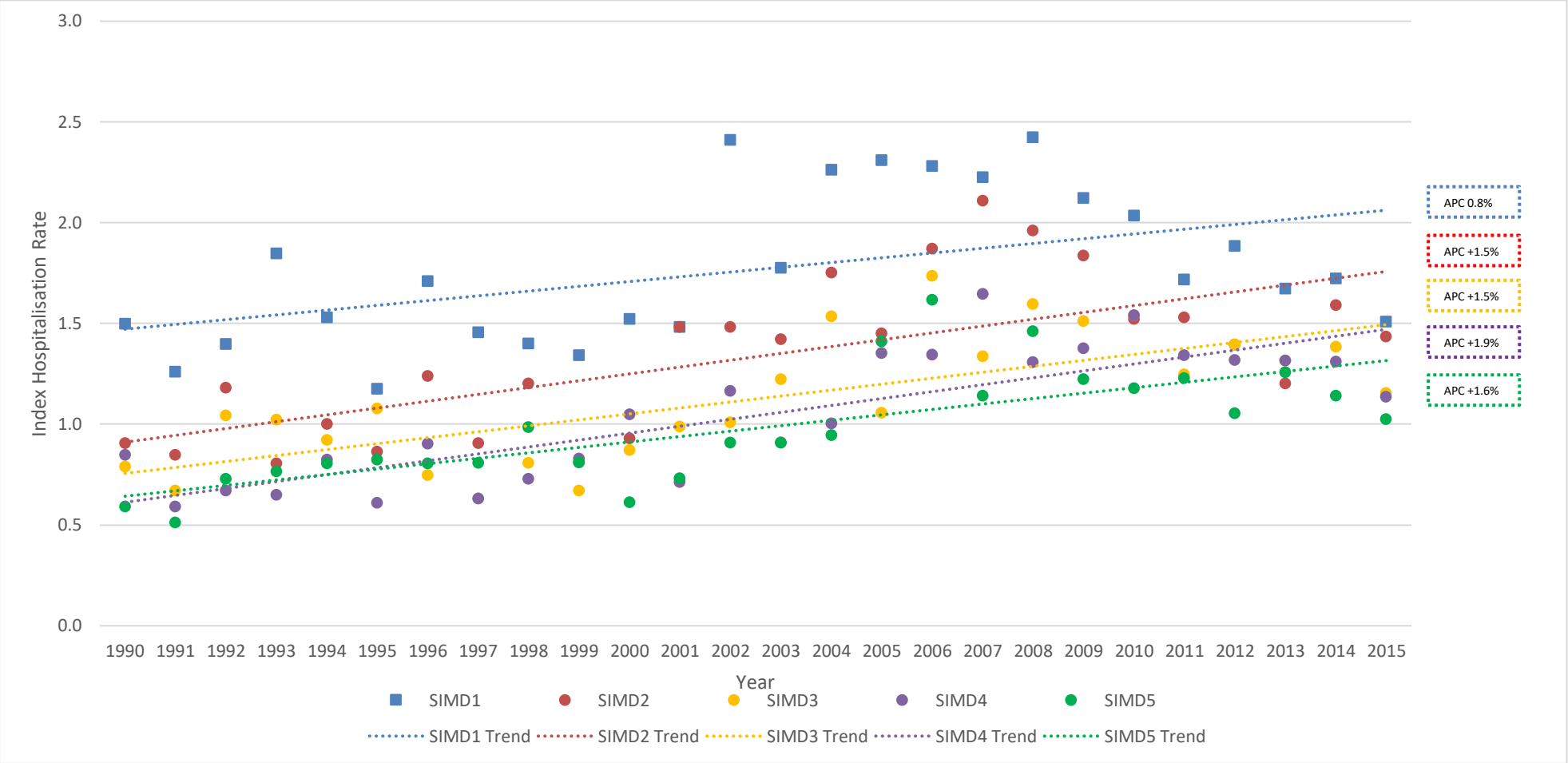
Index hospitalisation rates for patients with mild CHD lesion complexity CHD in the 3rd quintile (3rd most deprived) ranged from 0.8 (95% CI 0.5-1.0) in 1990 to 1.2 (95% CI 0.9-1.4) in 2015. 2006 had the highest index hospitalisation rate of 1.7 (95% CI 1.4-2.1). The 3rd SIMD quintile had the 3rd highest index hospitalisations of lesions of mild complexity comprising of 18.0% the total mild lesion index hospitalisations.

Index hospitalisation rates for patients with mild CHD lesion complexity CHD in the 4th quintile (2nd least deprived) ranged from 0.8 (95% CI 0.6-1.1) in 1990 to 1.1 (95% CI 0.9-1.4) in 2015. 2007 had the highest index hospitalisation rate of 1.6 (95% CI 1.3-2.0). The 4th SIMD quintile had the 4th highest index hospitalisations of lesions of mild complexity comprising of 16.7% the total mild lesion index hospitalisations.

Index hospitalisation rates for patients with mild CHD lesion complexity CHD in the 5th quintile (least deprived) ranged from 0.6 (95% CI 0.4-0.8) in 1990 to 1.0 (95% CI 0.8-1.3) in 2015. 2006 had the highest index hospitalisation rate of 1.6 (95% CI 1.3-2.0). The 5th SIMD quintile had the least index hospitalisations of lesions of mild complexity comprising of 15.7% ($p<0.05$) the total mild lesion index hospitalisations.

Figure 8-7 shows the index hospitalisation rates per year in each of the SIMD quintiles for patients with CHD lesions of mild complexity.

Figure 8-7 Index hospitalisation rates of patients with CHD lesions of mild complexity in SIMD 1-5



Index hospitalisation rate per annum for individuals with CHD lesions of mild complexity in SIMD quintiles 1 (most deprived – 5 (least deprived) expressed as rate per 100 000 of the general population. The blue square represents the index hospitalisation rate in SIMD1, the red circle SIMD2, the yellow circle SIMD3, the purple circle SIMD4 and the green circle SIMD5. Blue dotted line represents the APC trend for SIMD1, the red dotted line for SIMD2, the yellow dotted line for SIMD3, the purple dotted line for SIMD4 and the green dotted line for SIMD5.

There was no increase in the annual index hospitalisation rate in SIMD1. There was an annual increase in the index hospitalisation rate in the remaining quintiles. There was a 1.5% (95% CI 0.9 – 2.0%, p<0.05) annual increase in SIMD2, a 1.5% (95%CI 0.9 – 2.0%, p<0.05) annual increase in SIMD3, a 1.9% (95% CI 1.4 – 2.3%, p<0.05) annual increase in SIMD4 and a 1.6% (95%CI 1.1 – 2.1%, p<0.05) annual increase in SIMD5.

8.3.4.2 Moderate Lesion Complexity and Deprivation

The index hospitalisation rates for individuals with CHD lesions of moderate complexity, per 100 000 of the Scottish population can be found in Table 8-9.

Table 8-9 Index hospitalisations rate of patients with lesions of moderate complexity (100 000 of the Scottish population

	SIMD Quintiles				
Year	**1 (95% CI)**	**2 (95% CI)**	**3 (95% CI)**	**4 (95% CI)**	**5 (95% CI)**
1990	1.2(0.9-1.5)	0.5(0.3-0.7)	0.8(0.5-1.0)	0.7(0.5-1.0)	0.7(0.5-0.9)
1991	1.4(1.1-1.7)	0.8(0.6-1.1)	0.5(0.3-0.6)	0.7(0.5-0.9)	0.5(0.3-0.7)
1992	1.1(0.8-1.4)	0.8(0.6-1.1)	0.8(0.6-1.1)	0.5(0.3-0.6)	0.8(0.6-1.1)
1993	1.4(1.1-1.7)	0.7(0.5-0.9)	0.8(0.5-1.0)	0.7(0.5-0.9)	0.6(0.4-0.8)
1994	1.3(1.0-1.6)	1.0(0.7-1.3)	0.8(0.6-1.1)	0.7(0.5-1.0)	0.5(0.3-0.8)
1995	1.1(0.8-1.4)	1.1(0.8-1.4)	0.7(0.4-0.9)	0.6(0.4-0.8)	0.6(0.4-0.9)
1996	1.7(1.4-2.1)	1.8(1.4-2.1)	1.3(1.0-1.6)	1.2(0.9-1.5)	1.0(0.8-1.3)
1997	1.4(1.0-1.7)	1.3(1.0-1.6)	1.1(0.8-1.4)	0.9(0.7-1.2)	0.7(0.5-0.9)
1998	0.9(0.6-1.1)	1.1(0.8-1.4)	0.7(0.5-0.9)	0.6(0.4-0.9)	0.7(0.5-0.9)
1999	1.3(1.0-1.7)	0.7(0.5-1.0)	0.8(0.5-1.0)	0.9(0.6-1.1)	0.8(0.6-1.1)
2000	1.2(0.9-1.6)	1.0(0.7-1.3)	0.9(0.6-1.1)	1.0(0.7-1.3)	0.8(0.5-1.0)
2001	1.2(0.9-1.5)	1.0(0.7-1.3)	0.8(0.5-1.0)	1.0(0.7-1.3)	0.8(0.6-1.1)
2002	1.1(0.8-1.4)	0.9(0.6-1.1)	0.8(0.6-1.1)	0.6(0.3-0.8)	0.9(0.6-1.2)
2003	1.0(0.7-1.3)	0.9(0.6-1.2)	0.6(0.4-0.9)	0.5(0.3-0.7)	0.6(0.4-0.8)
2004	0.9(0.7-1.2)	1.0(0.7-1.3)	0.9(0.6-1.1)	0.7(0.5-1.0)	0.9(0.6-1.1)
2005	1.0(0.7-1.3)	0.8(0.6-1.0)	0.9(0.7-1.2)	0.6(0.4-0.8)	0.8(0.6-1.0)
2006	1.1(0.8-1.4)	1.0(0.7-1.2)	1.1(0.9-1.4)	0.6(0.4-0.8)	0.5(0.3-0.7)
2007	0.9(0.6-1.1)	0.9(0.6-1.2)	0.9(0.7-1.2)	0.8(0.6-1.1)	0.7(0.5-1.0)
2008	0.9(0.7-1.2)	0.9(0.6-1.1)	0.9(0.6-1.1)	0.7(0.4-0.9)	0.6(0.4-0.8)
2009	1.0(0.7-1.2)	0.8(0.6-1.1)	0.7(0.5-1.0)	0.8(0.5-1.0)	0.6(0.4-0.8)
2010	1.0(0.7-1.2)	1.0(0.7-1.3)	1.0(0.7-1.3)	0.6(0.4-0.9)	0.8(0.6-1.1)
2011	1.2(0.9-1.5)	0.8(0.6-1.1)	1.1(0.8-1.4)	0.9(0.6-1.1)	0.8(0.5-1.0)
2012	1.1(0.9-1.4)	1.1(0.9-1.4)	0.9(0.6-1.1)	0.9(0.7-1.2)	0.7(0.5-1.0)
2013	1.1(0.8-1.4)	0.8(0.6-1.1)	1.0(0.7-1.2)	0.8(0.6-1.1)	0.8(0.6-1.1)
2014	1.0(0.7-1.2)	0.9(0.6-1.1)	1.2(0.9-1.5)	0.9(0.6-1.2)	0.8(0.6-1.0)
2015	1.0(0.7-1.3)	1.1(0.8-1.4)	1.0(0.8-1.3)	1.0(0.8-1.3)	0.9(0.6-1.1)

The index hospitalisation rate for patients with moderate CHD lesion complexity CHD in the 1st quintile (most deprived) ranged from 1.2 (95% CI 0.9-1.5) in 1990 to 1.0 (95% CI 0.7-1.3) in 2015. 1996 had the highest index hospitalisation rate of 1.7 (95% CI 1.4-2.1). The 1st SIMD quintile had the highest index hospitalisations of lesions of moderate complexity comprising 25.2% ($p<0.05$) of the total moderate lesion index hospitalisations.

The index hospitalisation rate for patients with moderate CHD lesion complexity CHD in the 2nd quintile ranged from 0.5 (95% CI 0.3-0.7) in 1990 to 1.1 (95% CI 0.8-1.4) in 2015. 1996 had the highest index hospitalisation rate of 1.8 (95% CI 1.4-2.1). The 2nd SIMD quintile had the 2nd most index hospitalisations of lesions of moderate complexity comprising of 21.3% the total moderate lesion index hospitalisations.

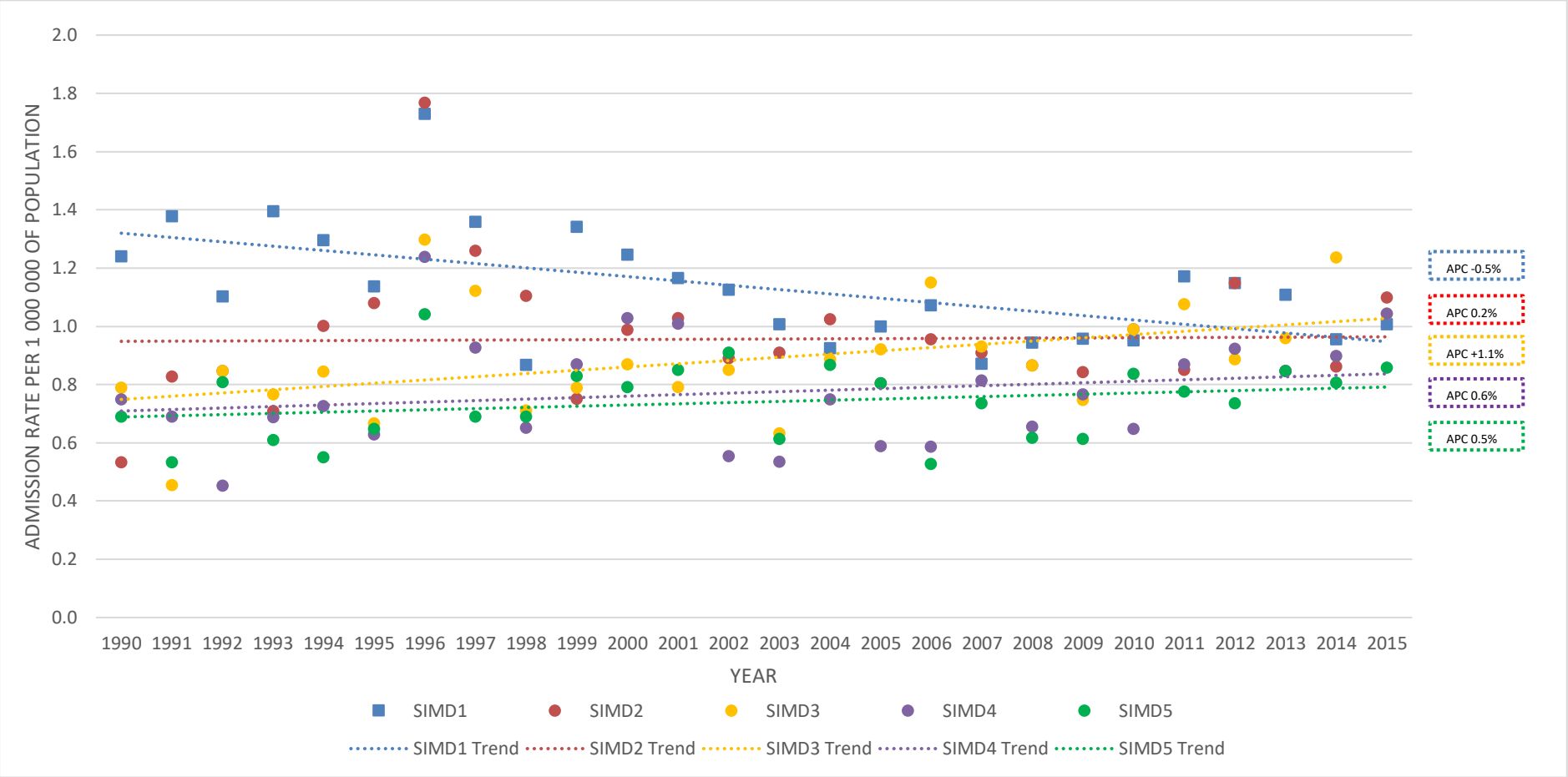
The index hospitalisation rate for patients with moderate CHD lesion complexity CHD in the 3rd quintile ranged from 0.8 (95% CI 0.5-1.0) in 1990 to 1.0 (95% CI 0.8-1.3) in 2015. 1996 had the highest index hospitalisation rate of 1.3 (95% CI 1.0-1.6). The 3rd SIMD quintile had the 3rd most index hospitalisations of lesions of moderate complexity comprising 19.8% of the total moderate lesion index hospitalisations.

The index hospitalisation rate for patients with moderate CHD lesion complexity CHD in the 4th quintile ranged from 0.7 (95% CI 0.5-1.0) in 1990 to 1.0 (95% CI 0.8-1.3) in 2015. 1996 had the highest index hospitalisation rate of 1.2 (95% CI 0.9-1.5). The 4th SIMD quintile had the 4th most index hospitalisations of lesions of moderate complexity comprising 17.2% of the total moderate lesion index hospitalisations.

The index hospitalisation rate for patients with moderate CHD lesion complexity CHD in the 5th quintile ranged from 0.7 (95% CI 0.5-0.9) in 1990 to 0.9 (95% CI 0.6-1.1) in 2015. 1996 had the highest index hospitalisation rate of 1.0 (95% CI 0.8-1.3). The 5th SIMD quintile had the fewest index hospitalisations of lesions of moderate complexity comprising 16.5% of the total moderate lesion index hospitalisations.

Figure 8-8 shows the index hospitalisation rates per year in each of the SIMD quintiles for patients with CHD lesions of moderate complexity.

Figure 8-8 Index hospitalisation rates of patients with CHD lesions of moderate complexity in SIMD 1-5



Index hospitalisation rate per annum for individuals with CHD lesions of moderate complexity in SIMD quintiles 1 (most deprived – 5 (least deprived) expressed as rate per 100 000 of the general population. The blue square represents the index hospitalisation rate in SIMD1, the red circle SIMD2, the yellow circle SIMD3, the purple circle SIMD4 and the green circle SIMD5. Blue dotted line represents the APC trend for SIMD1, the red dotted line for SIMD2, the yellow dotted line for SIMD3, the purple dotted line for SIMD4 and the green dotted line for SIMD5.

There was a 0.5% (95% CI -2.1 – 1.1%, p<0.05) annual decrease in the index hospitalisation rate in lesions of moderate complexity in SIMD1. There was no change in the annual index hospitalisation rate in SIMD2 (APC 0.2% (95% CI -1.5 – 1.1%, p=0.6%)). There was a 1.1% (95% CI 0.1 – 2.2%, P<0.05) annual increase in the index hospitalisation rate in SIMD3. There was no change in the annual index hospitalisation rate in SIMD 4 and 5 (APC 0.6% (95% CI -0.7 – 1.8%, p=0.4) and 0.5% (95% CI -0.4 – 1.4%, p=0.3)) respectively.

8.3.4.3 Great Lesion Complexity and Deprivation

The index hospitalisation rates for individuals with CHD lesions of great complexity, per 100 000 of the Scottish population can be found in Table 8-10.

Table 8-10 Index hospitalisations rate of patients with lesions of great complexity (100 000 of the Scottish population (95% CI))

	SIMD Quintiles				
Year	**1 (95% CI)**	**2 (95% CI)**	**3 (95% CI)**	**4 (95% CI)**	**5 (95% CI)**
1990	0.6(0.3-0.8)	0.4(0.2-0.5)	0.2(0.1-0.3)	0.2(0.1-0.3)	0.2(0.1-0.3)
1991	0.6(0.4-0.8)	0.4(0.2-0.5)	0.4(0.2-0.5)	0.3(0.2-0.5)	0.2(0.1-0.4)
1992	0.5(0.3-0.7)	0.4(0.2-0.5)	0.2(0.1-0.3)	0.3(0.1-0.4)	0.2(0.1-0.3)
1993	0.5(0.3-0.7)	0.3(0.2-0.5)	0.3(0.2-0.5)	0.3(0.1-0.4)	0.3(0.1-0.4)
1994	0.5(0.3-0.7)	0.3(0.1-0.4)	0.2(0.1-0.3)	0.2(0.1-0.3)	0.2(0.1-0.3)
1995	0.5(0.3-0.7)	0.4(0.2-0.5)	0.4(0.2-0.6)	0.3(0.2-0.5)	0.3(0.1-0.4)
1996	0.4(0.2-0.6)	0.5(0.3-0.8)	0.3(0.1-0.4)	0.2(0.1-0.3)	0.3(0.1-0.4)
1997	0.5(0.3-0.6)	0.4(0.2-0.5)	0.4(0.2-0.6)	0.2(0.1-0.3)	0.2(0.1-0.4)
1998	0.3(0.1-0.4)	0.4(0.2-0.5)	0.3(0.1-0.4)	0.1(0.0-0.2)	0.1(0.0-0.2)
1999	0.4(0.3-0.6)	0.3(0.1-0.4)	0.3(0.1-0.4)	0.2(0.1-0.4)	0.1(0.0-0.2)
2000	0.4(0.2-0.6)	0.4(0.2-0.5)	0.3(0.1-0.4)	0.1(0.0-0.2)	0.2(0.1-0.3)
2001	0.4(0.2-0.6)	0.2(0.1-0.3)	0.2(0.1-0.4)	0.2(0.1-0.3)	0.2(0.1-0.3)
2002	0.4(0.2-0.5)	0.2(0.1-0.4)	0.2(0.1-0.3)	0.2(0.0-0.3)	0.2(0.0-0.3)
2003	0.4(0.2-0.6)	0.3(0.2-0.5)	0.3(0.2-0.5)	0.1(0.0-0.2)	0.2(0.0-0.3)
2004	0.3(0.2-0.5)	0.4(0.2-0.6)	0.2(0.1-0.4)	0.4(0.2-0.5)	0.3(0.1-0.4)
2005	0.4(0.2-0.5)	0.4(0.2-0.5)	0.3(0.2-0.5)	0.2(0.1-0.3)	0.2(0.1-0.4)
2006	0.3(0.2-0.5)	0.1(0.0-0.2)	0.1(0.0-0.2)	0.2(0.1-0.4)	0.0(0.0-0.1)
2007	0.3(0.2-0.5)	0.3(0.1-0.4)	0.2(0.1-0.3)	0.3(0.1-0.4)	0.2(0.2-0.3)
2008	0.3(0.2-0.5)	0.3(0.2-0.5)	0.3(0.2-0.5)	0.2(0.1-0.3)	0.2(0.1-0.4)
2009	0.4(0.3-0.6)	0.4(0.2-0.6)	0.3(0.1-0.4)	0.3(0.1-0.4)	0.2(0.0-0.3)
2010	0.4(0.3-0.6)	0.2(0.1-0.3)	0.3(0.1-0.4)	0.3(0.1-0.4)	0.2(0.1-0.4)
2011	0.5(0.3-0.7)	0.4(0.2-0.6)	0.4(0.2-0.5)	0.2(0.1-0.3)	0.2(0.1-0.4)
2012	0.5(0.3-0.7)	0.3(0.2-0.5)	0.2(0.1-0.4)	0.2(0.1-0.3)	0.2(0.1-0.4)
2013	0.4(0.2-0.6)	0.3(0.1-0.4)	0.3(0.1-0.4)	0.2(0.1-0.4)	0.3(0.2-0.5)
2014	0.3(0.2-0.4)	0.2(0.1-0.3)	0.1(0.0-0.2)	0.2(0.1-0.3)	0.1(0.0-0.2)
2015	0.4(0.2-0.5)	0.2(0.1-0.3)	0.5(0.3-0.7)	0.3(0.2-0.5)	0.2(0.1-0.3)

The index hospitalisation rate for patients with great CHD lesion complexity CHD in the 1st quintile (most deprived) ranged from 0.6 (95% CI 0.3-0.8) in 1990 to 0.4 (95% CI 0.2-0.5) in 2015. The 1st SIMD quintile had the highest index hospitalisations of lesions of great complexity comprising of 28.0% the total great complexity CHD index hospitalisations.

The index hospitalisation rate for patients with great CHD lesion complexity CHD in the 2nd quintile (most deprived) ranged from 0.4 (95% CI 0.2-0.5) in 1990 to 0.2 (95% CI 0.1-0.3) in 2015. The 2nd SIMD quintile had the 2nd most index hospitalisations of lesions of great complexity comprising of 21.9% the total great complexity CHD index hospitalisations.

The index hospitalisation rate for patients with great CHD lesion complexity CHD in the 3rd quintile (most deprived) ranged from 0.2 (95% CI 0.1-0.3) in 1990 to 0.2 (95% CI 0.3-0.7) in 2015. The 3rd SIMD quintile had the 3rd most index hospitalisations of lesions of great complexity comprising of 18.4% the total great complexity CHD index hospitalisations.

The index hospitalisation rate for patients with great CHD lesion complexity CHD in the 4th quintile (2nd least deprived) ranged from 0.2 (95% CI 0.1-0.3) in 1990 to 0.3 (95% CI 0.2-0.5) in 2015. The 4th SIMD quintile had the 4th most index hospitalisations of lesions of great complexity comprising of 16.9% the total great complexity CHD index hospitalisations.

The index hospitalisation rate for patients with great CHD lesion complexity CHD in the 5th quintile (least deprived) ranged from 0.2 (95% CI 0.1-0.3) in 1990 to 0.2 (95% CI 0.1-0.3) in 2015. The 5th SIMD quintile had the least index hospitalisations of lesions of great complexity comprising of 14.8% the total great complexity CHD index hospitalisations.

Figure 8-9 shows the index hospitalisation rates per year in each of the SIMD quintiles for patients with CHD lesions of great complexity.

Figure 8-9 Index hospitalisation rates of patients with CHD lesions of great complexity in SIMD 1-5

Index hospitalisation rate per annum for individuals with CHD lesions of great complexity in SIMD quintiles 1 (most deprived – 5 (least deprived) expressed as rate per 100 000 of the general population. The blue square represents the index hospitalisation rate in SIMD1, the red circle SIMD2, the yellow circle SIMD3, the purple circle SIMD4 and the green circle SIMD5. Blue dotted line represents the APC trend for SIMD1, the red dotted line for SIMD2, the yellow dotted line for SIMD3, the purple dotted line for SIMD4 and the green dotted line for SIMD5.

There was a 1.4% (95% CI -2.3 - -0.6%, p<0.05) annual decrease in the index hospitalisation rate in SIMD1. There was no change in the annual index hospitalisation rate of the remaining SIMD quintiles (SIMD2 0.4% (-1.2 – 0.3%, p=0.2), SIMD3 0.7% (-0.8 – 2.3%, p=0.3), SIMD4 0.1% (-1.5 – 1.4%, p=0.9) and SIMD 5 0.2% (-1.3 – 0.4), p=0.6).

8.3.5 APC Summary

Table 8-11 contains a summary of the APC index hospitalisations with respect SIMD quintile. Where there were multiple joinpoints in the APC temporal trend one should refer to the corresponding figure for that cohort. A significant increase (p<0.05) in the APC is prefixed by a "+" and a significant decrease (P<0.05) in the APC is prefixed by a "-".

Table 8-11 Summary table of the APC for the studied SIMD quintiles

	SIMD Quintile	Index Hospitalisations (n)	Annual percentage change
All	1	4 852	No change
	2	3 824	+1.3
	3	3 339	+2.2
	4	3 019	+2.3
	5	2 818	+1.9
Paediatric (ages <16 years)	1	2 779	No change
	2	2 015	No change
	3	1 725	+1.5
	4	1 528	+1.5
	5	1 392	No change
Adult (ages ≥16 years)	1	2 073	+3.7
	2	1 809	+2.5
	3	1 614	+3.7
	4	1 419	+3.8
	5	1 426	+3.9
Mild Lesion Complexity	1	2 369	No change
	2	1 793	+1.5
	3	1 512	+1.5
	4	1 402	+1.9
	5	1 315	+1.6
Moderate Lesion Complexity	1	1 518	-0.5
	2	1 282	No change
	3	1 194	+1.1
	4	1 035	No change
	5	993	No change
Great Lesion Complexity	1	565	-1.4
	2	422	No change
	3	366	No change
	4	306	No change
	5	278	No change

+ significant increase in APC, $p<0.05$; - significant decrease in APC, $p<0.05$

8.4 Discussion

8.4.1 Basic Characteristics

What this study demonstrates is that there are inequalities relating to SED and CHD hospitalisation within Scotland with respect to overall index hospitalisations but also within age, sex, diagnosis and lesion complexity.

Although there was no difference between the number of males and females with an index hospitalisation (49.9% Vs 50.1%, p=0.8), there was disparity with respect to the levels of index hospitalisation and SED. There were significantly more females with an index hospitalisation in areas of higher SED (SIMD1) compared to that for males (52.5% Vs 47.5%, $p<0.05$), and less females than males (48.7% vs 51.3%, $p<0.05$) with an index hospitalisation in areas of less SED (SIMD 5). This is not the same for the general population where there is approximately equal proportions of males and females in each SIMD quintile. The cause for this concerning finding remains unclear and has not been directly demonstrated anywhere else in the literature. While one presumes that the cause of this observation is multi-factorial, possible influences may include the gender pay gap which exists in both the UK and Scotland being exacerbated by the presence of CHD. In Scotland in 2018 it was estimated that the gender pay gap for full time employees was 5.7%, equating to a median hourly pay of £11.81 for women and £13.81 for men.[138] It is possible that employers perception of the disability that can be associated with CHD is differently applied towards women compared to men.

8.4.2 Overall Index Hospitalisations

In patients with CHD the proportion of index hospitalisations in SIMD1 (27.2%, $p<0.05$) was higher, as was the rate of index hospitalisation, compared to any other SIMD quintile. There was an increase in the annual index hospitalisation rate in each of the SIMD quintiles (except SIMD1 where there was no change) The annual percentage change in the index hospitalisation rate ranged from 1.3-2.3%.

This disparity with respect to SED and index hospitalisations indicates that there is either a larger number of patients with CHD living in areas of higher SED, or

that those patients with CHD living in areas of SED are more likely to require hospitalisation, or a combination of the two seems most likely. The published literature surrounding this is limited. Tillman et al.[139] studied emergency department attendance and hospitalisation with respect to SED and known CHD. They found a larger number of patients with CHD residing in areas of higher deprivation and higher number of emergency department attendances and hospitalisation in the areas with the most deprivation. The same group demonstrated higher requirements of cardiovascular procedures among individuals from more deprived areas including pacemakers, cardiac surgery and cardiac catheterisation as well as a higher likelihood of experiencing major adverse cardiac events when compared to those individuals from the least deprived areas. Although one study showed that patients with CHD from more deprived areas had lower peak oxygen consumption and heart rate reserve compared to those patients in less deprived areas[140], causality has not yet been fully demonstrated. When extrapolating findings from patients with acquired heart disease it has been reported that patients with chronic heart failure living in more deprived areas are likely to require hospitalisation[141,142] and individuals residing in more deprived areas have higher rates of all-cause and cardiovascular related mortality[143].

Data from PHS reporting measures of SED in hospitalisations (and not inpatient episodes) for the general population in Scotland is available from 2011 onwards.[90] This data shows that there was an increase in the number of SIMD1 (most deprived) hospitalisations from 295 211 in 2011 to 308 685 in 2015 with a 1.0% (0.1 – 1.9%, $p<0.05$) annual increase in the hospitalisation rate in patients in SIMD1. With comparison to the APC in SIMD1 index hospitalisation rate for patients with CHD there was no difference between the two cohorts. There was an increase in the number of SIMD5 (least deprived) hospitalisations in the general population from 182 210 in 2011 to 196 552 to 2015 with a 1.7% (1.1 – 2.3%, $p<0.05$) annual increase in the hospitalisation rate in patients in SIMD1. With comparison to the CHD in SIMD5 index hospitalisation rates for patients with CHD there was no difference between the two cohorts.

Although studies examining the temporal association of CHD index hospitalisation and SED have not been widely published, index hospitalisation

and measures of deprivation have been reported in other conditions. Picciotto et al.[144] studied the association of area-based deprivation status with the incidence of first coronary event in Rome, Italy. They found that areas with increased levels of SED were strongly related to the incidence of index coronary events, particularly in women. Bing et al.[145] studied the outcomes of hospitalised cardiac arrests in Scotland at the time of index hospitalisation. They found that most patients hospitalised (>50%) were from SIMD1 and 2 (most deprived) and that higher deprivation was an independent predictor of 30-day mortality. Milne et al.[146] in their study of index COPD hospitalisation in New Zealand found that increased levels of SED was associated with an increased rate of index hospitalisation (as well as rehospitalisation) in the general population. Innes et al.[147] in their study of hospitalisation of major depression reported increased index hospitalisation rates were seen in areas of greater SED.

8.4.3 Age

The distribution of index hospitalisations within SIMD quintiles was similar in both the adult (age ≥ 16) and paediatric (age <16) age groups. In both age groups, there was significantly more ($p<0.05$) index hospitalisations in SIMD1 (most deprived) and significantly less ($p<0.05$) index hospitalisations in SIMD5 (least deprived).

When interpreting paediatric deprivation, we are by proxy interpreting that of their parents (if they continue to live within the same household). SIMD is a residence measure and not an individual measure defined by factors including income, employment, health, education, skills & training etc. When trying to explain why paediatric individuals with CHD who come from an area of higher deprivation are more likely to have CHD and/or CHD hospitalisations, one must consider family factors, including:

- *Cigarette smoking* – In Scotland, smoking has a prevalence of 32% among SIMD Quintile 1 (most deprived) compared with 8% in SIMD Quintile 5[148]. Foetal exposure to cigarette smoke, either directly or through passive smoking, during pregnancy has been reported to increase the risk of CHD in children, particularly septum and right-sided obstructive defects[149].

- *Maternal BMI* – In Scotland, 35% of women in the most deprived areas (SIMD 1) have a BMI >30kg/m^2 compared with 20% of women from the least deprived areas[150]. Higher maternal BMI is a risk factor for offspring CHD, particularly septal defects, hypoplastic left heart, congenital aortic stenosis and Tetralogy of Fallot[151].

- *Type 2 diabetes mellitus* – individuals in the most deprived areas are more likely to have a diagnosis of type 2 diabetes mellitus compared with other less deprived areas[152]. Maternal diabetes is known to increase the risk of all congenital anomalies, but especially cardiac lesions with congenital heart disease reported in 5% of infants of mothers with type 2 diabetes.[153,154]

- *Exposure to environmental teratogens* – exposure to environmental substances such as dioxins and pesticides is known to increase risk of CHD, especially in the very early stages of pregnancy.[155]

However, other factors must also play a role when it appears that high levels of SED appear to persist from paediatric life to adulthood. Education is likely to play a central role in this. Children who are born with lesions of moderate and great complexity are likely to require cardiac surgery on at least one occasion in childhood. While some of these interventions can be timed to occur around school holidays, this is often not the case. Cardiac surgery and the subsequent recovery period results in lost time in education. Neurodevelopmental delay has been reported in children undergoing complex CHD surgery, with effects persisting into adolescence and adulthood.[156] Girouard et al.[157] reported that children with CHD miss more days at school and have lower educational attainment than the general population. As a result, children with CHD are less likely to be employed than their peers. Therefore, although education directly affects one of the domains used in SIMD stratification, it has an indirect effect on employment, skills and income and housing[157] These barriers against social mobility for paediatric patients with CHD mean that the likelihood of experiencing higher levels of deprivation as they get older increase.

Whilst there have been relatively stable index hospitalisation rates over time within the paediatric age groups (only increasing in paediatric SIMD 3 and 4)

there were increasing index hospitalisation rates across all deprivation quintiles in adult hospitalisation rates, ranging between 2.5-3.9%, $p<0.05$. One possible explanation for this is that the overall index hospitalisation rate is increasing for adults and that this is reflected across the spectrum of deprivation quintiles. However, it is likely that the associations of CHD and SED discussed in this Chapter thus far impact adults more so than in the paediatric age group.

As survival with CHD increases, the population of adult men and women of reproductive age is also increasing. Although the genetics and inheritance of CHD is poorly understood, it is nevertheless recognised that the child of a mother or father who are directly affected by CHD or have a first-degree relative are with CHD, are at higher risk of having children with CHD[155]. With an already higher prevalence of adults with CHD residing in areas of higher SED, the likelihood of having children born in these areas also increases.

Care for all patients in Scotland with CHD is based on a hub-and-spoke healthcare model, with a central hub offering the majority of the specialist diagnostic modalities and the only access to surgical and percutaneous intervention. This provides geographical inequality to patients who reside out with the central belt. Although travel costs are subsidised by health boards it is not completely alleviated. Time is required to travel to and from these appointments for outpatient care, investigations and recovery time following surgery or procedures is cumulative. Parents of children with CHD and patients with CHD themselves require time off work to travel to these appointments. Not all employers are understanding, with some patients and parents taking annual or unpaid leave to make these trips. All of which come with a financial burden that may be more affordable to some more than others.

8.4.4 Lesion Complexity

Among all 3 lesion complexity groups, SIMD1 had the highest levels of index hospitalisations ($p<0.05$) indicating that despite the underlying lesion or severity, higher deprivation is a risk factor for index hospitalisation with CHD.

While the reasons why patients with lesions of moderate and great complexity may experience higher levels of deprivation compared to the general population

have already been discussed in this Chapter, the cause of individuals with mild complexity CHD experiencing higher levels of SED is not as clear. While this is speculative, it seems most likely that lesions of mild complexity are associated with higher levels of CHD, rather than perpetuating higher SED itself. Vereczkey, Malik and Pawluk et al.[158–160] also reported a similar finding among lesions of mild complexity and reported that VSDs and septal defects had a higher incidence among individuals from areas with higher SED. None of these studies concluded causality but hypothesised that the cause of the increased prevalence of lesions of mild complexity within areas of higher SED in their study was due to a myriad of factors including the environmental, familial and maternal factors that I have postulated in the discussion thus far. However, 2 studies[127,161]in the USA reported that although the was overall increased prevalence of CHD within areas of higher SED, that prevalence of lesions of mild complexity were higher among areas of lower SED and hypothesised that this was as a result of better access to health care. The translation of these findings from an insurance-based, fee-paying health care system to that of free, universal healthcare is not directly comparable to individuals with CHD in the Scotland.

8.5 Conclusion

Areas of increased SED in Scotland have a higher incidence of CHD index hospitalisation. Inequalities persist in sex, age and for underlying CHD lesion complexity. This study has highlighted for the first time in Scotland the disparity that exists with respect to SED and index hospitalisations, and although I have hypothesised causality, the true nature of this have yet to be determined.

9 Final Discussion

9.1 Summary of Findings

The studies contained within this thesis aimed to describe the index hospitalisation of individuals in Scotland with CHD between the years 1990 and 2015. This has been achieved by describing temporal changes in index hospitalisation diagnosis based on underlying CHD lesion and lesion complexity as well as sex, age and SED. Using SMR to identify index hospitalisation diagnosis of CHD, at a national level, I have identified 17 900 patients who have required hospitalisation on at least one occasion, where an ICD diagnostic code or OPCS code pertaining to CHD appears in their SMR record. To date this is the largest study describing the index hospitalisation of both children and adults with CHD in Scotland. The studies unequivocally demonstrate increasing CHD index hospitalisation rates in Scotland. The index hospitalisation rate has risen from 108.6 per 1 000 000 million of the general population in 1990 to 150.9 in 2015 (39% increase), with an increasing annual hospitalisation rate of 1.5%.

Index hospitalisations have been reported in other chronic cardiac conditions. Jhund et al.[88] studied the index hospitalisation of heart failure in Scotland and found a decrease in index hospitalisation rates in males (124 to 105 per 100 000, 15%) and females (128 to 101 per 100 000, 21%) between 1986 and 2003. Lewsey et al.[162] examined the index hospitalisation of stroke in Scotland between 1986 and 2005. They reported a rise in index hospitalisation from stroke in both men (20.6 to 26.4 per 100 000, 28%) and women (17.5 to 22.4 per 100 000, 28%) in those aged <55 years old. Berry et al.[163] examined the index hospitalisation of aortic valve disease in Scotland between 1997 and 2005 and reported an increase in index hospitalisation rate from 246 to 365 per 1 000 000 (48% increase) of the population. Briffa et al.[164] reported a decreasing annual rate of 1.1% in atrial fibrillation index hospitalisations in Western Australia between 1995 and 2010. Schmidt et al.[165] reported a decrease of in index hospitalisation rates of myocardial infarction in both men (410 to 213 per 100 000, 48%) and women (209 to 131 per 100 000, 37%) between 1984 and 2008 in Denmark.

The strength in my collection of studies is that they are based on diagnostic coding of hospitalisations in a healthcare system that is available nationwide and free at the point of access. The potential for selection bias that lies within data collected from single centre cohort registries and on remuneration data from

privatised healthcare systems has been negated by using this method of patient identification.

Chapter 5 describes index hospitalisation of patients with CHD with a focus on lesions and complexity of CHD. Defects of the atrial septum were the most common CHD diagnosis in all ages, however VSDs were the most common lesion identified in children. Almost half of all individuals with an index hospitalisation had CHD lesions of mild complexity. Moderate complexity lesions were the second largest lesion grouping followed by great complexity lesions. The increasing index hospitalisation rates appear to be driven by increasing rates of ASDs, TGA with arterial switches, congenital valvular lesions and other CHD lesion diagnoses as they had significant increasing annual index hospitalisation rates. There was no change in the index hospitalisation rates of moderate and great complexity CHD lesions.

Chapter 6 illustrates the sex differences in CHD index hospitalisation. Overall, there is no difference between index hospitalisation in either sex. However, more boys than girls had an index hospitalisation with CHD in childhood. Women had higher rates of index hospitalisation than men in adulthood. This is reflected in the different median age at index hospitalisation (mean age 27 for women and 23 for men). More women than men experienced CHD lesions of mild complexity, whereas men had higher rates of moderate and great complexity lesions. Women have higher rates of SED compared to men, with significantly more women in SIMD1 (most deprived) compared to men, and subsequently less women than men in SIMD5 (least deprived). Over time index hospitalisation rates for both sexes are increasing at a significant rate, although more so in adult men and women compared to boys and girls. Rates of index hospitalisation remain relatively stable over the study period for lesions of moderate and great complexity. Mild lesion index hospitalisations appear to fluctuate over time with a significant increase in index hospitalisations up to 2007, before reducing up to 2015.

Chapter 7 describes CHD index hospitalisations with respect to age. Index hospitalisation occurred more often in the paediatric age groups compared with that of adults. Within the paediatric age group, CHD is most often diagnosed within the 1st year of life. Crude live birth incidence is consistent with that in

published literature. The median age at index hospitalisation was 2 in all patients (mean adult age was 52 and 2 in paediatrics). 100% of index hospitalisations with TGA and arterial switch was observed in paediatric patients. The lesions with greatest number of adult index hospitalisations were ASDs, VSDs, aortic lesions, Ebstein's and congenital valvular and other CHD lesions. This is in keeping with the pathophysiology of these underlying lesions. Unless significantly haemodynamically significant at a young age, many of these lesions go either undiagnosed until later in life or are longitudinally assessed over time as an outpatient, until such times as intervention is required due to symptoms or haemodynamic parameters meeting evidence-based criteria for intervention. Temporal trends in age of index hospitalisation demonstrated that there was an increase in infant (age<1) diagnosis of CHD. All adults (age ≥16 years) and younger adults (age 20-59 years) had increasing annual index hospitalisation rates. The largest increase in the annual index hospitalisation rate was observed in the younger adult cohort (age 20-59 years).

Chapter 8 illustrates the relationship between CHD index hospitalisations and SED. Areas in Scotland with increased levels of SED had higher CHD index hospitalisation rates compared to areas with less SED, suggesting an increased prevalence of CHD within these areas. Both adults and children in SIMD1 had higher index hospitalisations than other SIMD quintiles. The overall proportion of children in SIMD1 was larger than that of adults. Across all congenital lesions, index hospitalisation levels were higher in SIMD1 than in other deprivation quintiles (except for Ebstein's and TGA arterial switch). As a result, SIMD1 had higher index hospitalisation among all CHD lesion severity groups. Over time the index hospitalisation rate in all SIMD quintiles is increasing (except for SIMD1).

9.2 Implications

At present the requirement to achieve a certificate of completion of training in adult cardiology in the UK requires a 2-week placement within a specialist ACHD surgical centre. This along with exposure to patients with CHD presenting to emergency departments, coronary care units, cardiology receiving units and outpatient clinics set up most cardiologists limited experience with CHD. Anecdotally most trainees and non-ACHD cardiologists are apprehensive about the prospect of a patient with CHD presenting under their care. This thesis

demonstrates that the population of patients requiring index hospitalisation growing, including in those patients over the age of 60, who are likely to present with both cardiac and non-cardiac complaints and require cardiology input to provide specialist advice on medical, surgical and peri-operative care. With pressures on medical training at a premium, this thesis should be used to ensure that Scottish (and UK) cardiology trainees achieve more training time in ACHD units to gain exposure, experience and confidence in managing patients in this increasing population of complex patients. By encouraging ACHD training time is extended for cardiology trainees, hopefully some of the anxiety surrounding ACHD will lessen and allow trainees (and soon-to-be consultants) to think of ACHD as general cardiology in a well-defined group of patients with alternative cardiac anatomy (at birth or post-operatively) and physiology from patients with acquired heart disease.

Whilst I have not demonstrated the primary reason for index hospitalisation (cardiac or non-cardiac), the literature would suggest that the incidence of non-cardiac morbidity and mortality is increasing within the CHD population.[166] Altered cardiac physiology in CHD patients with lesions of moderate or great complexity means that the standard treatment for certain conditions is not suitable (or in many cases not evidence based) and an integrated multi-disciplinary approach is required to facilitate delivery of optimal care. Specialties that will benefit from this multi-disciplinary team approach will include (but are not limited to) obstetricians due to the increase number of women with CHD reaching childbearing age[167], gastroenterologists due to the longer term effects of chronically elevated venous pressures resulting in congestive hepatopathy[168], respiratory physicians due to the high incidence of restrictive lung disease seen following multiple midline sternotomies[169] and to oncologists due to the increased incidence of cancer among adults with CHD.[170] One must not forget that general practitioners play a central role in facilitating care. We must ensure they are involved, educated and enabled to help meet the complex needs for patient group in a primary care environment.

These studies have demonstrated that the population of adults with CHD is increasing. It is well recognised that this group requires life-long interval follow up from a specialist ACHD centre to allow longitudinal functional cardiac

assessment. An increasing population of complex patients requires increased health resource allocation to provide inpatient and outpatient services to meet this demand. Considerations must include appropriate and accessible outpatient facilities that caters for a national cohort of patients, access to diagnostic testing (including ECG, echocardiograms, cardiopulmonary exercise testing, CT and MRI) and human resources and training to ensure that the services are adequately maintained (including clinicians, specialist nurses, physiologists, radiologists and administration staff). As previously discussed, the care for patients with CHD in Scotland is provided in a hub-and-spoke model, and therefore many of these resources will need to be emulated within the spokes within the all the Scottish health boards and not just in the central hub. An adequate outreach service from the specialist SACCS team will also need to help facilitate the safe delivery of care within each regional spoke.

Many patients will require one or more percutaneous or cardiac surgical intervention within their lifetime. The purpose of outpatient follow-up, as described above, is to allow longitudinal assessment of cardiac function and patient symptoms to allow timely intervention, if or when it is required. With increasing prevalence of patients the numbers and complexity of these interventions will also follow that trend. Implications of this will include the provision of trained theatre and catheterisation laboratory staff, increased number of congenital cardiac surgeons, cardiac anaesthetists, intensive care beds and staff to facilitate peri-operative care, as well as adequate post-operative ward space to allow the recuperation and rehabilitation of patients. Elements of this body of work have already been used by the SACCS team to present national data to central health bodies on the need for immediate investment in both inpatient and outpatient services for CHD nationwide.

The collection of studies presented here has implications not only on the services providing care for adults, but also to those providing care for paediatric patients with CHD. I have demonstrated increasing hospitalisation rates among infants and shown that 53% of hospitalisations in the paediatric cohort have lesions of moderate or great complexity. The investment in infrastructure and human resources for paediatric care goes in parallel with that described in the adult sector above. Increased collaboration with paediatric cardiologists will be

required to ensure that the transition of care from children to adult services is improved and maintained. Thus, enabling the sharing of knowledge and experience of cardiac morbidity associated with CHD palliation in adults to ensure that we strive towards better longer-term outcomes for all patients with CHD.

As well as demonstrating increasing index hospitalisation rates among individuals with CHD, I have also shown the inequality that patients with CHD experience, with respect to SED. Health inequality is a well-recognised consequence of SED, worldwide and in Scotland. For example, the life expectancy in Jordanhill, which is in an affluent area in the West End of Glasgow, is 78.0 for men and 83.8 for women. However, 7 stops along the trainline through the city centre to the less affluent East End area in Bridgeton, the life expectancy is 14.3 years less for men and 11.7 years less for women.[171] Chapter 8 describes the links between SED and CHD in Scotland for the first time. Not only did this study demonstrate that patients with mild, moderate and great complexity lesions all experience higher levels of SED, it also demonstrated that paediatric cohorts and females with CHD experience higher levels of SED compared with adults and males respectively. Work is currently underway as a consequence of these findings to describe and understand morbidity and mortality among patients with CHD in Scotland, with particular relevance to measures of SED. One would imagine that increased levels of morbidity and mortality will follow that of index hospitalisation rates in areas of higher SED. If this is the case, then it is incumbent on us as clinicians to address it at a local and national level, working alongside public health bodies in the hope that it would inevitably help shape and influence future government policy.

9.3 Limitations

There is a degree of fragility in the methodology used to categorise patients in to mild, moderate and great complexity depending on their underlying CHD diagnosis. For example, a patient with an ASD or VSD will be classed as having a lesion of mild complexity. However, if this same patient has reversal of their left-to-right shunt and develops Eisenmenger syndrome, then they would have a lesion of great complexity. There is an ICD-10 code for Eisenmenger syndrome. However, to identify these patients in the absence of case note review, there

requires the presence of both the ICD code for the shunt and the code for Eisenmenger syndrome to be identified. This is a reasonable, but extreme example, but other such examples include patients with Tetralogy of Fallot or coarctation of the aorta and concomitant severe left ventricular systolic dysfunction. This means that patients with lesions of mild and moderate complexity are more likely to be underestimated, and the true number of patients are thought to be higher than what was identified as a result of this body of work. Similarly, those patients without a hospitalisation, or with a hospitalisation where the CHD diagnostic ICD code was not recorded (in the primary or secondary position) will not have been counted.

One other such limitation of the Bethesda Classification system is that it relies on original cardiac anatomy to correlate with complexity, and not that of post-cardiac status or current physiology. The most recent AHA/ACC guidelines on the management of adults with congenital heart disease[40] made recommendations that a new classification system be implemented which incorporates both anatomic and physiological classification to stratify complexity into 12 groups in an attempt to provide a more comprehensive assessment of an individual's risk of morbidity and mortality. Subsequent studies have showed promise in validating this new classification model.[172]

The identification of patients in this thesis is built upon clinical coding. Accuracy of clinical coding depends on two factors. The experience and knowledge of the clinical coder (which is validated on a regular basis by ISD) and the quality and clarity of the underlying code descriptors. As discussed elsewhere, ICD does not cater for post-operative cardiac anatomy. There have been improvements in the quality of the clinical code descriptors between ICD 9 and 10, with improved clarity of description of the underlying cardiac defect allowing better discrimination of cardiac defects. One such area that should be improved upon in future versions of ICD is separation in diagnosis of ASD and PFO. Although they are similar in terms of their location within the heart, PFO is not alone a pathogenic entity and only in the co-existence of paradoxical emboli is it thought to be implicit in a disease-causing process. Similarities could be drawn to the presence of the oropharyngeal tonsils or the appendix. Although they are present in every individual, they are not in themselves a

pathogenic structure and only in certain circumstance do they cause morbidity (and mortality).

Small hospitalisation numbers were observed in several lesion groups e.g. Fontan, SRV, TGA Switch, Ebstein's and AVSD. As a result, there is a wide variation in index hospitalisation rates and wide confidence intervals. It is difficult to draw conclusions about the trends in these lesion groups and more meaningful trends are represented when they are grouped together along with lesions of similar complexity. This highlights the fragility of the methods used to identify this heterogenous group of individuals.

Population studies rely on estimation of SED by means of application of regional based deprivation estimation scoring. SIMD and Carstairs Morris are two such examples. Not all individuals will experience the same degree of SED in each region, and therefore reported SED are area, and not an individual estimates of deprivation. Despite this, the use of these deprivation models is widely accepted.

Although more than half of older adult (≥60 years) index hospitalisations have a CHD diagnosis of ASD and congenital valvular lesions, without access to clinical notes or imaging I have been unable to categorise those older adults included in the data as true CHD or older adults with PFO, haemodynamic insignificant ASD with no history of paradoxical embolic events or acquired valve heart disease from true CHD. The anonymity of patients must be respected, and only once a national registry of patients with CHD is created will this limitation of clinical coding and population-based census of CHD be solved.

Infant (age <1) index hospitalisation is the closest estimation I can accurately use to describe the birth prevalence of CHD in Scotland. Permission was granted to identify patients only of their age year at admission to hospital (and not date of birth, date of admission and date of discharge) to maintain robust anonymity of the data. Although the crude prevalence estimate is similar to published data, the true incidence and prevalence of CHD within Scotland will inevitably be underestimated from my study as hospitalisation with a CHD diagnosis was required for inclusion. It is more likely that the underestimate will affect those

patients with lesions of mild and moderate complexity more than complex lesions.

9.4 Recommendations For Future Work

This study has identified index hospitalisations as a surrogate means of identifying the population of patients with CHD in Scotland. Subsequent rehospitalisation (or all CHD hospitalisations) along with length of hospital stay would give a more in depth understanding of the true burden of nationwide CHD hospitalisations in Scotland and allow better comparison with the hospitalisation data presented within the literature review. With many CHD operative procedures facilitating a palliative repair and not a cure, time from primary CHD procedure and/or intervention to rehospitalisation would allow longitudinal assessment of the durability of repair offered by surgical interventions within Scotland.

While I have indicated that further work is already underway regarding morbidity and mortality of patients with CHD in Scotland as a result of the analyses presented, any further studies should aim to investigate the reasons for such a disparity in hospitalisation rates seen amongst those patients with CHD from a more deprived background. What would certainly be of interest, would be to explore if factors such as race, gestational age, housing and area of residence (urban or rural) had any influence on CHD hospitalisation, as well as adding to the arguments of SED being an association or causal effect of CHD.

Although this is the largest population study of CHD within Scotland there are areas which could be improved upon to allow more thorough means of assessment of this growing population of individuals. If one were to design a comprehensive nationwide registry of patients with CHD in Scotland to undertake a thorough epidemiological assessment, one would identify patients with CHD in all sectors of healthcare and age including foetal diagnosis (some of which may lead to termination), at birth, neonatally as well as during paediatric and adult healthcare settings, reflecting the life-long nature of CHD and the many interactions that it has with various healthcare environments. Linkage of systems including outpatients and primary healthcare providers would provide a more rounded, longitudinal assessment of the lifelong burden of CHD. Individual

functional assessment would be included, for example New York Heart Association classification or performance status as would degree of underlying valvular or systemic or sub-pulmonary ventricular dysfunction. One would also want to include the existence of significant comorbidity such as arrhythmia, pulmonary hypertension, symptomatic heart failure, ischaemic heart disease as well as non-cardiac morbidity including diabetes and chronic kidney disease. This would be a significant investment, both in terms of the financial burden to build and create, but also in the human resourcing to ensure that the quality and standards of a registry of this size is maintained.

This thesis is another example of the fortunate position we are in in Scotland of having a comprehensive linked hospitalisation discharge record (SMR). Another example of a linked system is the dispensing of community-based prescriptions, made available using the Prescribing Information System (PIS). Although pharmacoepidemiology will not replace that of randomised controlled trials, one must appreciate that congenital cardiology falls behind that of most of the rest of acquired cardiology with its plethora of evidence-based practice and large scaled randomised trials. This lack of large-scale trials in CHD has largely been due to inadequate recruitment and homogeneity within the target population. The identification of patients with CHD by use of SMR records and linkage to PIS would allow observational study in the use of cardiovascular medicines within this well-defined target population. Prescribing costs, longitudinal trends in cardiovascular prescribing as well as observation of adverse events in the use of novel medications, such as direct oral anticoagulants or new heart failure therapy in acquired heart disease (angiotensin receptor-neprilysin inhibitors or sodium-glucose cotransporter-2 inhibitors) are a few such examples that could be easily investigated. Other non-cardiac prescriptions could also be studied among the CHD population from this such as the use of anti-depressants and anti-psychotics or oral contraceptives.

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Appendix A

Table 1 Index hospitalisation rate per annum for individuals with CHD (indexed to 1 000 000 general population)

Year Admitted	Hospitalisation Rate	95% CI
1990	108.6	99.6 –117.7
1991	102.7	93.9 -111.5
1992	115.2	105.9 -124.**6**
1993	116.8	107.5 -126.2
1994	116.8	107.4 -126.2
1995	110.1	101.0 -119.2
1996	152.8	142.1 -163.5
1997	124.7	115.0 -134.4
1998	113.5	104.2 -122.7
1999	113.8	104.5 -123.1
2000	121.7	112.1 -131.3
2001	126.0	116.2 -135.8
2002	132.3	122.2 -142.3
2003	120.9	111.4 -130.5
2004	145.9	135.4 -156.4
2005	145.2	134.8 -155.7
2006	153.9	143.2 -164.6
2007	156.1	145.3 -166.9
2008	158.6	147.8 -169.4
2009	150.8	140.3 -161.3
2010	151.5	140.9 -162.0
2011	153.2	142.7 -163.8
2012	146.2	136.0 -156.5
2013	144.9	134.7 -155.1
2014	151.7	141.2 -162.1
2015	150.9	140.6 -161.3

Table 2 Index hospitalisation rate per annum for individuals with ASD (indexed to 1 000 000 general population)

Year Admitted	Hospitalisation rate	95% CI
1990	14.8	11.4 - 18.1
1991	11.6	8.6 - 14.6
1992	16.5	13.0 - 20.1
1993	15.7	12.3 - 19.2
1994	16.3	12.8 - 19.8
1995	14.5	11.2 - 17.8
1996	18.1	14.4 - 21.8
1997	18.3	14.6 - 22.0
1998	22.5	18.3 - 26.6
1999	20.5	16.6 - 24.5
2000	21.1	17.1 - 24.1
2001	23.9	19.6 - 28.2
2002	34.7	29.6 - 39.9
2003	33.9	28.9 - 39.0
2004	44.1	38.3 - 49.8
2005	46.2	40.3 - 52.1
2006	51.6	45.4 - 57.8
2007	50.7	44.5 - 56.8
2008	55.7	49.3 - 62.2
2009	48.9	42.9 - 54.9
2010	42.2	36.6 - 47.7
2011	35.5	30.4 - 40.5
2012	36.1	31.0 - 41.2
2013	38.1	32.8 - 43.3
2014	39.6	34.3 –45.0
2015	37.2	32.1 - 42.4

Table 3 Index hospitalisation rate per annum for individuals with PDA (indexed to 1 000 000 general population)

Year Admitted	Hospitalisation Rates	95% CI
1990	12.8	9.7– 15.9
1991	11.0	8.1 -13.9
1992	16.5	13.0 -20.1
1993	16.9	13.3 -20.5
1994	12.4	9.3 -15.4
1995	10.2	7.4 -13.0
1996	14.5	11.2 -17.8
1997	8.7	6.1 -11.2
1998	7.5	5.1 -9.9
1999	8.5	5.9 -11.0
2000	10.5	7.7 -13.3
2001	13.4	10.2 -16.6
2002	13.2	10.0 -16.4
2003	10.9	8.0 -13.7
2004	10.8	8.0 -13.7
2005	11.7	8.8 -14.7
2006	14.0	10.8 -17.3
2007	13.5	10.4 -16.7
2008	12.9	9.8 -16.0
2009	14.0	10.8 -17.2
2010	18.4	14.8 -22.1
2011	17.7	14.2 -21.3
2012	14.3	11.1 -17.5
2013	13.3	10.2 -16.4
2014	13.3	10.2 -16.4
2015	9.9	7.2 -12.5

Table 4 Index hospitalisation rate per annum for individuals with VSD (indexed to 1 000 000 general population)

Year Admitted	Hospitalisation Rate	95% CI
1990	20.1	16.2 -24.0
1991	17.1	13.5 -20.7
1992	17.5	13.9 -21.1
1993	19.1	15.3 -22.8
1994	22.5	18.4 -26.7
1995	21.0	17.0 -24.9
1996	22.0	17.9 -26.1
1997	17.5	13.9 -21.2
1998	21.9	17.8 -25.9
1999	15.6	12.1 -19.0
2000	18.2	14.5 -21.9
2001	16.8	13.2 -20.4
2002	22.1	18.0 -26.2
2003	17.6	13.9 -21.2
2004	20.7	16.7 -24.6
2005	18.4	14.7 -22.1
2006	23.0	18.8 -27.1
2007	21.1	17.1 -25.0
2008	19.6	15.8 -23.4
2009	18.2	14.5 -21.8
2010	17.7	14.1 -21.3
2011	18.3	14.7 -21.9
2012	20.5	16.7 -24.4
2013	16.7	13.2 -20.2
2014	19.1	15.4 -22.8
2015	16.4	13.0 -19.8

Table 0 Index hospitalisation rate per annum for individuals with AVSD (indexed to 1 000 000 general population)

Year Admitted	Hospitalisation Rate	95% CI
1990	6.1	3.9 – 8.3
1991	6.5	4.3 -8.7
1992	8.7	6.1 -11.2
1993	6.3	4.1 -8.5
1994	6.5	4.3 -8.7
1995	7.2	4.9 -9.6
1996	9.0	6.4 -11.6
1997	9.2	6.6 -11.9
1998	6.9	4.6 -9.2
1999	7.1	4.8 -9.4
2000	9.1	6.5-11.7
2001	9.1	6.5 -11.7
2002	5.7	3.6 -7.9
2003	4.9	3.0 -6.9
2004	7.1	4.8 -9.4
2005	6.7	4.4 -8.9
2006	6.2	4.1 -8.4
2007	7.2	4.9 -9.5
2008	3.5	1.9 -5.1
2009	6.1	4.0 -8.2
2010	5.1	3.2 -7.1
2011	3.6	2.0 -5.2
2012	5.1	3.2 -7.0
2013	6.8	4.6 -9.0
2014	3.9	2.3 -5.6
2015	5.0	3.1- 6.9

Table 6 Index hospitalisation rate per annum for individuals with aortic anomalies (indexed to 1 000 000 general population)

Year Admitted	Hospitalisation Rate	95% CI
1990	20.3	16.4 -24.2
1991	18.1	14.4 -21.8
1992	19.5	15.6 -23.3
1993	20.6	16.7 -24.6
1994	22.7	18.6 -26.9
1995	21.0	17.0 -24.9
1996	33.8	28.7 -38.8
1997	21.4	17.4 -25.5
1998	14.0	10.7 -17.2
1999	14.0	10.7 -17.3
2000	13.8	10.6 -17.1
2001	14.2	10.9 -17.5
2002	11.8	8.9 -14.8
2003	10.9	8.0 -13.7
2004	12.2	9.2 -15.2
2005	8.4	5.9 -10.9
2006	12.9	9.8 -16.0
2007	11.6	5.7 -14.5
2008	12.1	9.1 -15.1
2009	10.5	7.7 -13.3
2010	12.0	9.0 -14.9
2011	14.2	11.0 -17.4
2012	11.7	8.8 -14.6
2013	10.1	7.4 -12.8
2014	9.5	6.6 -12.2
2015	8.8	6.3 -11.3

Table 7 Index hospitalisation rate per annum for individuals with Ebstein's anomaly (indexed to 1 000 000 general population)

Year Admitted	Hospitalisation Rate	95% CI
1990	0.6	0.0 - 1.3
1991	1.2	0.2 -2.1
1992	1.0	0.1 -1.8
1993	1.2	0.2 -2.1
1994	0.8	0.0 -1.6
1995	0.8	0.0 -1.6
1996	0.6	0.0 -1.3
1997	0.6	0.0 -1.3
1998	0.8	0.0 -1.6
1999	1.2	0.2 -2.1
2000	2.2	0.9 -3.5
2001	0.6	0.0 -1.3
2002	0.4	0.0 -0.9
2003	0.8	0.0 -1.6
2004	1.2	0.2 -2.1
2005	1.2	0.2 -2.1
2006	2.0	0.7 -3.2
2007	0.8	0.0 -1.5
2008	0.8	0.0 -1.5
2009	0.4	0.0 -0.9
2010	0.4	0.0 -0.9
2011	0.8	0.0 -1.5
2012	1.1	0.2 -2.0
2013	0.6	0.0 -1.2
2014	1.1	0.2 -2.0
2015	0.6	0.0 -1.2

Table 8 Index hospitalisation rate per annum for individuals with ToF (indexed to 1 000 000 general population)

Year Admitted	Hospitalisation Rate	95% CI
1990	7.7	5.3 - 10.1
1991	6.9	4.6 - 9.2
1992	6.9	4.6 - 9.2
1993	5.1	3.1 - 7.1
1994	6.3	4.1 - 8.4
1995	6.3	4.1 - 8.4
1996	7.5	5.1 - 9.8
1997	5.7	3.6 - 7.9
1998	4.9	3.0 - 6.9
1999	5.9	3.8 - 8.0
2000	7.1	4.8 - 9.4
2001	5.5	3.5 - 7.6
2002	5.5	3.5 - 7.6
2003	5.1	3.2 - 7.1
2004	6.5	4.3 - 8.7
2005	7.6	5.2 - 10.0
2006	6.6	4.4 - 8.9
2007	6.4	4.2 - 8.6
2008	6.2	4.0 - 8.3
2009	4.8	2.9 - 6.7
2010	5.1	3.2 - 7.1
2011	3.0	1.5 - 4.5
2012	5.3	3.3 - 7.2
2013	4.9	3.0 - 6.8
2014	4.9	3.0 - 6.7
2015	4.3	2.5 - 6.0

Table 9 Index hospitalisation rate per annum for individuals with TGA switch (indexed to 1 000 000 general population)

Year Admitted	Hospitalisation Rate	95% CI
1990	0.0	0.00
1991	0.0	0.00
1992	0.0	0.00
1993	0.2	0.0 - 0.6
1994	0.8	0.0 -1.6
1995	0.6	0.0 -1.3
1996	2.0	0.8 -3.2
1997	2.2	0.9 -3.4
1998	1.0	0.1 -1.9
1999	1.4	0.4 -2.4
2000	1.6	0.5 -2.7
2001	2.2	0.9 -3.5
2002	1.6	0.5 -2.7
2003	1.0	0.1 -1.9
2004	1.4	0.4 -2.4
2005	1.6	0.5 -2.7
2006	2.7	1.3 -4.2
2007	1.2	0.2 -2.1
2008	3.8	2.2 -5.6
2009	2.1	0.9 -3.3
2010	2.6	1.4 -4.3
2011	3.0	1.5 -4.5
2012	3.4	1.8 -5.0
2013	2.6	1.3 -4.0
2014	2.1	0.8 -3.3
2015	1.3	0.3 -2.3

Table 10 Index hospitalisation rate per annum for individuals with systemic right ventricle (indexed to 1 000 000 general population)

Year Admitted	Hospitalisation Rate	95% CI
1990	1.4	0.4 – 2.4
1991	2.6	1.2 – 4.0
1992	0.8	0.0 - 1.6
1993	2.2	0.8 - 3.4
1994	1.2	0.2 - 2.1
1995	1.2	0.2 - 2.1
1996	1.4	0.4 - 2.4
1997	0.4	0.0 - 0.9
1998	0.8	0.0 - 1.6
1999	1.0	0.1 - 1.9
2000	0.8	0.0 - 1.6
2001	0.6	0.0 - 1.2
2002	0.6	0.0 - 1.3
2003	1.0	0.1 -1.9
2004	1.8	0.6 - 2.9
2005	0.8	0.0 - 1.6
2006	0.6	0.0 - 1.2
2007	1.4	0.4 - 2.4
2008	0.6	0.0 - 1.2
2009	0.6	0.0 - 1.2
2010	0.6	0.0 - 1.2
2011	0.6	0.0 - 1.2
2012	0.2	0.0 - 0.6
2013	0.4	0.0 - 0.9
2014	0.6	0.0 - 1.2
2015	0.4	0.0 – 0.9

Table 11 Index hospitalisation rate per annum for individuals with Fontan (indexed to 1 000 000 general population)

Year Admitted	Hospitalisation Rate	95% CI
1990	2.4	1.0 – 3.7
1991	2.6	1.2 -4.0
1992	1.0	0.1 -1.8
1993	0.8	0.0 -1.6
1994	1.2	0.2 -2.1
1995	0.6	0.0 -1.3
1996	1.0	0.1 -1.8
1997	2.4	1.0 -3.7
1998	0.8	0.0 -1.6
1999	1.0	0.1 -1.9
2000	1.8	0.6 -2.9
2001	2.6	1.2 -4.0
2002	2.4	1.0 -3.7
2003	2.0	0.8 -3.2
2004	2.4	1.0 -3.7
2005	1.0	0.1 -1.8
2006	0.6	0.0 -1.3
2007	2.3	1.0 -3.6
2008	1.9	0.7 -3.1
2009	1.9	0.7 -3.1
2010	2.1	0.9 -3.3
2011	2.1	0.9 -3.3
2012	1.9	0.7 -3.2
2013	1.3	0.3 -2.3
2014	0.8	0.0 -1.5
2015	1.5	0.5 -2.5

Table 12 Index hospitalisation rate per annum for individuals with congenital valvular lesions (indexed to 1 000 000 general population)

Year Admitted	Hospitalisation rate	95% CI
1990	5.9	3.8 – 8.0
1991	6.1	4.0 -8.3
1992	5.3	3.3 -7.3
1993	8.6	6.1 -11.2
1994	7.6	5.2 -10.0
1995	5.7	3.6 -7.8
1996	18.3	14.6 -22.0
1997	14.6	11.2 – 17.9
1998	13.2	10.0 -16.4
1999	16.6	13.0 -20.1
2000	16.0	12.5 -19.5
2001	17.0	13.4 -20.6
2002	18.2	14.5 -21.9
2003	14.2	10.9 -17.5
2004	16.1	12.6 -19.6
2005	16.1	12.6 -19.5
2006	12.9	9.8 -16.0
2007	16.1	12.6 -19.5
2008	13.3	10.1 -16.4
2009	15.3	11.9 -18.6
2010	18.6	14.9 -22.3
2011	23.0	18.9 -27.1
2012	22.2	18.2 -26.2
2013	21.6	17.6 -25.5
2014	26.4	22.0 -30.7
2015	30.5	25.9 -35.2

Table 13 Index hospitalisation rate per annum for individuals with complex lesions (indexed to 1 000 000 general population)

Year Admitted	Hospitalisation Rate	95% CI
1990	12.2	9.2 – 15.2
1991	14.0	10.7 – 17.2
1992	14.2	10.9 – 17.4
1993	14.1	10.9 – 17.4
1994	11.6	8.6 – 14.5
1995	16.5	12.9 – 20.0
1996	14.5	11.2 – 17.8
1997	14.2	10.9 – 17.4
1998	9.5	6.8 – 12.1
1999	11.8	8.8 – 14.8
2000	11.5	8.5 – 14.4
2001	9.1	6.5 – 11.7
2002	7.9	5.5 – 10.3
2003	10.5	7.6 – 13.2
2004	12.2	9.2 – 15.2
2005	12.9	9.8 – 16.0
2006	7.6	5.2 – 10.0
2007	9.7	7.0 – 12.4
2008	11.7	8.8 – 14.7
2009	13.2	10.1 – 16.3
2010	11.4	8.5 – 14.3
2011	15.1	11.8 – 18.4
2012	13.2	10.1 – 16.3
2013	13.5	10.4 – 16.6
2014	7.5	5.2 – 9.8
2015	14.5	11.3 – 17.7

Table 14 Index hospitalisation rate per annum for individuals with other lesions (indexed to 1 000 000 general population)

Year Admitted	Hospitalisation Rate	95% CI
1990	4.5	2.7 – 6.4
1991	5.1	3.2 – 7.1
1992	7.5	5.1 – 9.9
1993	6.1	3.9 – 8.2
1994	7.1	4.8 – 9.4
1995	4.7	2.8 – 6.6
1996	10.2	7.4 – 13.0
1997	9.6	6.9 – 12.3
1998	9.9	7.1 – 12.6
1999	9.3	6.6 – 11.9
2000	8.1	5.6 – 10.6
2001	11.1	8.2 – 14.0
2002	8.1	5.6 – 10.6
2003	8.3	5.8 – 10.8
2004	9.6	6.9 – 12.3
2005	12.7	9.6 – 15.8
2006	13.3	10.1 – 16.4
2007	14.3	11.1 – 17.8
2008	16.5	13.0 – 20.2
2009	14.9	11.6 – 18.2
2010	15.0	11.7 – 18.3
2011	16.4	13.0 – 19.9
2012	11.3	8.4 – 14.2
2013	15.0	11.7 – 18.3
2014	23.0	18.9 – 27.1
2015	20.7	16.8 – 24.5

Table 15 Index hospitalisation rate per year with a CHD lesion of mild complexity (per 1 000 00 population)

Year Admitted	Hospitalisation Rate	95% CI
1990	47.6	41.6 - 53.6
1991	39.7	34.3 -45.2
1992	50.5	44.4 -56.7
1993	51.6	45.4 -57.9
1994	51.2	45.0 -57.4
1995	45.7	39.8 -51.5
1996	54.6	48.2 -51.0
1997	44.5	38.7 -50.3
1998	51.8	42.5 -58.1
1999	44.6	38.8 -50.4
2000	49.8	43.6 -55.9
2001	54.1	47.7 -60.5
2002	70.1	62.8 -77.4
2003	62.4	55.5 -69.2
2004	75.5	68.0 -83.1
2005	76.3	68.7 -83.9
2006	88.6	80.5 -96.8
2007	85.3	77.3 -93.3
2008	88.2	80.2 -96.3
2009	81.0	73.3 -88.8
2010	78.3	70.7 -85.9
2011	71.5	64.3 -78.7
2012	71.0	63.8 -78.1
2013	68.1	61.1 -75.2
2014	72.0	64.8 -79.2
2015	63.5	56.7 -70.2

Table 16 Index hospitalisation rate per year with a CHD lesion of mild complexity (per 1 000 00 population)

Year Admitted	Hospitalisation Rate	95% CI
1990	40.5	35.0 -46.1
1991	38.8	33.3 -44.2
1992	41.3	35.7 -46.9
1993	42.0	36.4 -47.7
1994	44.7	38.9 -50.5
1995	41.5	36.0 -47.1
1996	71.1	63.8 -78.4
1997	53.7	47.3 -60.1
1998	40.8	35.2 -46.3
1999	46.1	40.2 -52.1
2000	49.8	43.6 -55.9
2001	48.6	42.5 -54.7
2002	43.2	37.5 -49.0
2003	36.9	31.6 -42.2
2004	44.5	38.7 -50.3
2005	41.5	35.9 -47.1
2006	43.3	37.6 -48.9
2007	43.1	37.5 -48.8
2008	39.6	34.2 -45.0
2009	39.2	33.8 -44.6
2010	44.1	38.4 -49.8
2011	47.6	41.7 -53.4
2012	48.7	42.8 -54.7
2013	46.6	40.8 -52.3
2014	47.9	42.0 -53.7
2015	50.4	44.4 -56.4

Table 17 Index hospitalisation rate per year with a CHD lesion of great complexity (per 1 000 00 population)

Year Admitted	Hospitalisation Rate	95% CI
1990	15.9	12.5 – 19.4
1991	19.1	15.3 – 22.9
1992	15.9	12.5 – 19.4
1993	17.1	13.5 – 20.7
1994	13.9	10.7 – 17.2
1995	18.2	14.5 – 21.9
1996	16.9	13.3 – 20.5
1997	16.9	13.3 - 20.5
1998	11.0	8.1 – 13.9
1999	13.8	10.6 – 17.0
2000	14.0	10.8 – 17.3
2001	12.2	9.2 – 15.3
2002	10.9	8.0 – 13.7
2003	13.4	10.2 – 16.6
2004	16.3	12.8 – 19.8
2005	14.7	11.4 – 18.0
2006	8.8	6.2 – 11.3
2007	13.4	10.2 – 16.5
2008	14.2	11.0 – 17.5
2009	15.6	12.2 – 19.1
2010	14.1	10.9 – 17.3
2011	17.7	12.3 – 21.3
2012	15.2	11.9 – 18.6
2013	15.2	11.9 – 18.5
2014	8.8	6.3 – 11.3
2015	16.4	13.0 – 19.8

Appendix B

Table 1 Index hospitalisation rates of males admitted per annum when indexed to the Scottish male population.

Year Admitted	Hospitalisation Rate	95% CI
1990	11.6	10.3 – 13.0
1991	11.2	9.8 - 12.5
1992	11.1	9.8 - 12.5
1993	11.4	10.1 - 12.7
1994	12.2	10.8 - 13.6
1995	11.3	10.0 - 12.7
1996	14.9	13.4 - 16.4
1997	13.0	11.6 - 14.5
1998	12.1	10.7 - 13.4
1999	11.3	9.9 - 12.6
2000	13.3	11.8 - 14.7
2001	13.1	11.7 - 14.6
2002	13.4	12.0 - 14.9
2003	12.1	10.7 - 13.5
2004	14.3	12.8 - 15.8
2005	14.6	13.0 - 16.1
2006	15.8	14.2 - 17.4
2007	15.1	13.6 - 16.7
2008	16.6	15.0 - 18.2
2009	16.2	14.6 - 17.7
2010	15.5	14.0 - 17.0
2011	16.1	14.6 - 17.7
2012	16.4	14.8 - 17.9
2013	14.5	13.2 - 16.0
2014	16.6	15.0 - 18.1
2015	17.1	15.5 - 18.7

Table 2 Index hospitalisation rates of females per annum when indexed to the Scottish female population.

Year Admitted	Hospitalisation Rate	95% CI
1990	10.2	8.9 – 11.4
1991	9.4	8.3 - 10.6
1992	11.9	10.6 - 13.2
1993	12.0	10.6 - 13.3
1994	11.2	9.9 - 12.5
1995	10.7	9.5 – 12.0
1996	15.7	14.1 - 17.2
1997	12.0	10.7 - 13.3
1998	10.7	9.4 - 11.9
1999	11.5	10.2 - 12.8
2000	11.1	9.9 - 12.4
2001	12.1	10.8 - 13.5
2002	13.0	11.7 - 14.4
2003	12.1	10.8 - 13.4
2004	14.9	13.4 - 16.3
2005	14.5	13.1 - 15.6
2006	15.0	13.5 - 16.5
2007	16.1	14.5 - 17.6
2008	15.2	13.7 - 16.7
2009	14.1	12.7 - 15.5
2010	14.8	13.4 - 16.3
2011	14.6	13.3 - 16.0
2012	13.0	11.6 - 14.3
2013	14.5	13.0 - 15.9
2014	13.9	12.5 - 15.2
2015	13.2	11.8 - 14.5

Table 3 Index Hospitalisation rate of boys when indexed to the Scottish male population <16

Year Admitted	Hospitalisation Rate	95% CI
1990	35.8	25.6 – 46.1
1991	38.3	28.1 – 48.5
1992	35.6	25.4 - 45.8
1993	35.3	25.0 - 45.6
1994	33.2	22.9 - 43.5
1995	34.1	23.8 - 44.4
1996	37.1	26.9 - 47.3
1997	39.7	29.6 - 49.8
1998	39.0	29.0 - 49.1
1999	35.1	25.1 - 45.1
2000	42.6	32.7 - 52.5
2001	40.2	30.5 – 50.0
2002	34.3	24.7 - 43.9
2003	36.6	27.1 - 46.1
2004	41.5	32.1 - 50.9
2005	36.7	27.4 - 46.1
2006	40.8	31.5 - 50.0
2007	39.6	30.3 - 48.8
2008	39.6	30.4 - 48.9
2009	43.3	34.0 - 52.5
2010	43.4	34.2 - 52.6
2011	43.9	34.8 - 53.1
2012	44.0	34.9 - 53.2
2013	36.9	27.8 - 46.0
2014	41.0	31.9 - 50.1
2015	39.5	30.3 - 48.6

Table 4 Index hospitalisation rate of girls when indexed to the Scottish female population <16.

Year Admitted	Hospitalisation Rate	95% CI
1990	34.7	29.6 - 39.9
1991	32.7	27.7 - 37.7
1992	40.0	34.5 - 45.6
1993	37.0	31.7 - 42.3
1994	32.3	27.3 - 37.2
1995	31.0	26.1 - 35.9
1996	41.3	35.7 – 47.0
1997	34.8	29.6 - 40.0
1998	33.5	28.4 - 38.6
1999	32.7	27.6 - 37.8
2000	32.3	27.2 - 37.4
2001	37.6	32.1 - 43.2
2002	37.4	31.9 – 43.0
2003	33.8	28.5 - 39.0
2004	39.1	33.3 - 44.8
2005	36.9	31.3 - 42.5
2006	36.9	31.3 - 42.5
2007	39.7	33.9 - 45.5
2008	36.7	31.1 - 42.3
2009	38.1	32.4 - 43.8
2010	46.0	39.7 - 52.3
2011	43.6	37.5 - 49.7
2012	40.5	34.6 - 46.4
2013	43.1	37.0 - 49.2
2014	40.4	34.5 - 46.3
2015	36.3	30.7 - 41.9

Table 5 Index hospitalisation rate for men per year when indexed to the Scottish male population ≥16.

Year Admitted	Hospitalisation Rate	95% CI
1990	5.0	4.0 – 6.0
1991	3.8	2.9 - 4.6
1992	4.5	3.5 - 5.4
1993	4.9	3.9 - 5.9
1994	6.4	5.3 - 7.6
1995	5.1	4.1 - 6.2
1996	8.9	7.6 - 10.2
1997	5.9	4.8 – 7.0
1998	4.9	3.9 - 5.9
1999	4.9	3.9 - 5.9
2000	5.6	4.6 - 6.7
2001	6.2	5.0 - 7.3
2002	8.2	6.9 - 9.4
2003	6.0	5.0 - 7.1
2004	7.7	6.5 - 8.9
2005	9.2	7.9 - 10.6
2006	9.9	8.5 - 11.3
2007	9.4	8.1 - 10.8
2008	11.3	9.8 - 12.7
2009	10.0	8.6 - 11.3
2010	9.2	7.9 - 10.5
2011	9.9	8.6 - 11.2
2012	10.2	8.8 - 11.6
2013	9.6	8.3 - 10.9
2014	11.2	9.8 - 12.6
2015	12.3	10.8 - 13.8

Table 0 Index hospitalisation rate for women per year when indexed to the Scottish female population ≥16.

Year Admitted	Hospitalisation Rate	95% CI
1990	4.5	3.6-5.3
1991	4.1	3.2 - 4.9
1992	5.3	4.4 - 6.3
1993	6.1	5.0 - 7.1
1994	6.3	5.2 - 7.3
1995	6.0	4.9 - 7.0
1996	9.7	8.4 - 11.0
1997	6.7	5.6 - 7.8
1998	5.5	4.5 - 6.5
1999	6.7	5.6 - 7.8
2000	6.4	5.3 - 7.4
2001	6.5	5.5 - 7.6
2002	7.8	6.6 - 8.9
2003	7.5	6.3 - 8.6
2004	9.7	8.4 - 11.0
2005	9.9	5.8 - 11.2
2006	10.5	9.2 - 11.9
2007	11.3	9.8 - 12.6
2008	10.9	9.5 - 12.2
2009	9.3	8.0 - 10.5
2010	8.7	7.4 - 9.9
2011	8.9	7.7 - 10.1
2012	7.6	6.5 - 8.7
2013	8.9	7.7- 10.1
2014	8.7	7.5 - 9.9
2015	8.7	7.5 - 9.9

Table 7 Index hospitalisation rates for males with a lesion of mild complexity indexed to 100 000 of the Scottish male population.

Year Admitted	Hospitalisation Rates	95% CI
1990	4.5	3.7 - 5.4
1991	3.7	2.9 - 4.4
1992	4.3	3.4 - 5.1
1993	4.5	3.7 - 5.3
1994	4.3	3.5 - 5.1
1995	4.2	3.4 - 5.0
1996	4.5	3.6 - 5.3
1997	4.3	3.5 - 5.2
1998	5.0	4.1 - 5.9
1999	4.0	3.2 - 4.8
2000	5.1	4.2 - 6.0
2001	5.4	4.5 - 6.5
2002	6.9	5.9 - 8.0
2003	5.5	4.6 - 6.4
2004	6.6	5.6 – 7.6
2005	6.9	5.9 – 7.8
2006	7.9	6.8 – 9.0
2007	8.2	7.1 – 9.3
2008	8.9	7.7 -10.1
2009	7.7	6.6 – 8.8
2010	7.7	6.6 – 8.8
2011	7.1	6.1 – 8.2
2012	7.4	6.4 – 8.5
2013	6.5	5.5 – 7.5
2014	6.8	5.8 – 7.8
2015	6.4	5.5 – 7.4

Table 8 Index hospitalisation rates for females with a lesion of mild complexity indexed to 100 000 of the Scottish female population.

Year Admitted	Hospitalisation Rate	95% CI
1990	5.0	4.1 – 5.8
1991	4.2	3.5 – 5.0
1992	5.8	4.9 – 6.7
1993	5.8	4.9 – 6.7
1994	5.9	4.9 – 6.8
1995	4.9	4.1 – 5.8
1996	6.4	5.4 – 7.4
1997	4.5	3.7 – 5.4
1998	5.4	4.5 – 6.3
1999	4.9	4.0 – 5.7
2000	4.9	4.1 – 5.8
2001	5.4	4.5 – 6.3
2002	7.1	6.1 – 8.1
2003	6.9	5.9 – 7.9
2004	8.5	7.3 – 9.6
2005	8.3	7.2 – 7.4
2006	9.8	8.6 – 10.1
2007	8.9	7.7 – 10.0
2008	8.7	7.6 – 9.9
2009	8.5	7.4 – 9.6
2010	8.0	6.9 – 9.0
2011	7.2	6.2 – 8.2
2012	6.8	5.8 – 7.7
2013	7.1	6.1 – 8.1
2014	7.5	6.5 – 8.6
2015	6.3	5.3 – 7.2

Table 9 Index hospitalisation rates for males with a lesion of moderate complexity indexed to 100 000 of the Scottish male population.

Year Admitted	Hospitalisation Rates	95% CI
1990	5.1	4.2 - 6.0
1991	4.8	3.9 - 5.7
1992	4.3	3.5 - 5.2
1993	4.3	3.5 - 5.2
1994	5.6	4.7 - 6.6
1995	4.6	3.8 - 5.5
1996	7.6	6.5 - 8.7
1997	5.9	4.9 - 6.8
1998	4.4	3.6 - 5.3
1999	4.7	3.8 - 5.5
2000	5.6	4.7 - 6.6
2001	5.2	4.3 - 6.1
2002	4.5	3.6 - 5.3
2003	4.1	3.3 - 4.9
2004	5.0	4.1 - 5.9
2005	4.8	3.9 - 5.6
2006	5.3	4.4 - 6.2
2007	4.2	3.4 - 5.1
2008	4.5	3.7 - 5.3
2009	5.1	4.2 - 6.0
2010	4.6	3.8 - 5.5
2011	5.3	4.4 - 6.2
2012	5.9	5.0 - 6.8
2013	5.1	4.2 - 5.9
2014	6.1	5.1 - 7.1
2015	6.2	5.3 - 7.2

Table 10 Index hospitalisation rates for females with a lesion of moderate complexity indexed to 100 000 of the Scottish female population.

Year Admitted	Hospitalisation Rate	95% CI
1990	3.1	2.4 - 3.8
1991	3.0	2.4 - 3.7
1992	3.9	3.2 - 4.7
1993	4.1	3.3 - 4.9
1994	3.4	2.7 - 4.1
1995	3.7	3.0 - 4.4
1996	6.6	5.6 - 7.6
1997	4.9	4.1 - 5.8
1998	3.8	3.0 - 4.5
1999	4.6	3.7 - 5.4
2000	4.4	3.6 - 5.2
2001	4.6	3.7 - 5.4
2002	4.2	3.4 - 5.0
2003	3.3	2.6 - 4.0
2004	3.9	3.2 - 4.7
2005	3.6	2.9 - 4.3
2006	3.4	2.7 - 4.1
2007	4.4	3.6 - 5.2
2008	3.5	2.8 - 4.2
2009	2.8	2.2 - 3.4
2010	4.2	3.4 - 5.0
2011	4.2	3.4 - 5.0
2012	3.9	3.2 - 4.7
2013	4.3	3.5 - 5.0
2014	3.6	2.9 - 4.3
2015	3.9	3.2 - 4.7

Table 11 Index hospitalisation rates for males with a lesion of great complexity indexed to 100 000 of the Scottish male population.

Year Admitted	Hospitalisation Rates	95% CI
1990	1.6	1.1 – 2.1
1991	2.2	1.6 - 2.8
1992	1.7	1.2 – 2.2
1993	1.8	1.3 – 2.3
1994	1.5	1.0 – 1.9
1995	2.1	1.5 – 2.7
1996	1.8	1.2 – 2.3
1997	1.9	1.4 – 2.5
1998	1.5	1.0 – 2.0
1999	1.5	1.0 – 2.0
2000	1.7	1.2 – 2.2
2001	1.2	0.7 – 1.6
2002	1.0	0.6 – 1.4
2003	1.7	1.2 – 2.2
2004	1.8	1.3 – 2.3
2005	1.6	1.1 – 2.1
2006	1.2	0.7 – 1.6
2007	1.4	0.9 – 1.9
2008	1.4	0.9 – 1.9
2009	1.8	1.3 – 2.3
2010	1.6	1.1 – 2.1
2011	1.8	1.3 – 2.4
2012	1.8	1.3 – 2.3
2013	1.5	1.0 – 2.0
2014	1.1	0.7 – 1.5
2015	1.9	1.4 – 2.4

Table 12 Index hospitalisation rates for females with a lesion of great complexity indexed to 100 000 of the Scottish female population.

Year Admitted	Hospitalisation Rate	95% CI
1990	1.6	1.1 – 2.1
1991	1.6	1.1 – 2.1
1992	1.5	1.0 – 2.0
1993	1.6	1.1 – 2.1
1994	1.3	0.9 – 1.8
1995	1.5	1.1 – 2.0
1996	1.6	1.1 – 2.1
1997	1.5	1.0 – 1.9
1998	0.8	0.4 – 1.1
1999	1.3	0.8 – 1.7
2000	1.1	0.7 – 1.5
2001	1.3	0.9 – 1.7
2002	1.2	0.8 – 1.6
2003	1.0	0.6 – 1.4
2004	1.5	1.0 – 1.9
2005	1.3	0.9 – 1.8
2006	0.6	0.3 – 0.9
2007	1.3	0.8 – 1.7
2008	1.5	1.0 – 1.9
2009	1.4	0.9 – 1.8
2010	1.2	0.8 – 1.6
2011	1.7	1.2 – 2.2
2012	1.3	0.9 – 1.7
2013	1.5	1.1 – 2.0
2014	0.7	0.4 – 1.0
2015	1.4	0.9 – 1.8

Appendix C

Table 1 Infant (age<1 years) index CHD hospitalisation rate per 100 000, years 1990 – 2015.

Year	Hospitalisation Rate	95% CI
1990	281.4	240.1 - 322.6
1991	304.2	262.1 - 346.4
1992	290.1	249.2 - 331.0
1993	303.0	260.4 - 345.7
1994	315.2	271.3 - 359.1
1995	327.1	281.4 - 372.7
1996	365.7	316.7 - 414.7
1997	370.6	321.7 - 419.4
1998	330.1	283.1 - 377.0
1999	318.4	271.8 - 365.1
2000	421.3	366.2 - 476.3
2001	405.6	350.8 - 460.3
2002	386.7	332.9 - 440.6
2003	394.0	339.9 - 448.0
2004	455.0	397.9 - 512.1
2005	442.2	386.4 - 498.0
2006	373.8	322.7 - 424.8
2007	429.5	375.8 - 483.3
2008	414.8	363.1 - 466.5
2009	445.9	392.3 - 499.5
2010	493.8	437.3 - 550.3
2011	487.0	431.4 - 542.7
2012	485.1	428.7 - 541.5
2013	426.3	372.7 - 479.9
2014	425.4	371.5 - 479.3
2015	416.1	362.6 - 469.5

Table 3 Index hospitalisation rate of Children (ages 1-15) with CHD per 100 000 of the population, years 1990 -2015

Year	Hospitalisation Rate	95% CI
1990	18.9	16.2 - 21.7
1991	17.1	14.4 - 19.7
1992	20.2	17.3 - 23.0
1993	18.4	15.7 - 21.1
1994	14.4	12.0 - 16.8
1995	14.3	11.9 - 16.6
1996	19.3	16.5 - 22.0
1997	16.4	13.8 - 19.0
1998	18.4	15.7 - 21.1
1999	16.9	14.3 - 19.6
2000	15.6	13.0 - 18.1
2001	18.2	15.4 - 20.9
2002	16.0	13.4 - 18.6
2003	14.4	11.9 - 16.9
2004	15.2	12.6 - 17.7
2005	11.6	9.4 - 13.9
2006	17.7	14.9 - 20.5
2007	14.0	11.5- 16.5
2008	12.2	9.8 - 14.5
2009	12.7	10.3 - 15.0
2010	13.6	11.2 - 16.1
2011	12.5	10.1 - 14.9
2012	12.0	9.7 - 14.4
2013	14.2	11.6 - 16.7
2014	15.4	12.8 - 18.1
2015	13.2	10.8 - 15.6

Table 3 Adult (age ≥16) index hospitalisation rate of patients with CHD per 100 000 of the population, years 1990 -2015

Year	Hospitalisation rate	95% CI
1990	4.7	4.1 – 5.4
1991	3.9	3.3 – 4.5
1992	4.9	4.2 – 5.6
1993	5.5	4.8 – 6.2
1994	6.3	5.6 – 7.1
1995	5.6	4.8 – 6.3
1996	9.3	8.4 – 10.2
1997	6.3	5.5 – 7.1
1998	5.2	4.5 – 5.9
1999	5.9	5.1 – 6.6
2000	6.0	5.3 – 6.8
2001	6.4	5.6 – 7.1
2002	8.0	7.1 – 8.8
2003	6.8	6.0 – 7.6
2004	8.8	7.9 – 9.7
2005	9.5	8.6 – 10.5
2006	10.2	9.3 – 11.2
2007	10.4	9.4 – 11.4
2008	11.0	10.1 – 12.0
2009	9.6	8.7 – 10.5
2010	8.9	8.0 – 9.8
2011	9.4	8.5 – 10.3
2012	8.9	8.0 – 9.7
2013	9.2	8.3 – 10.1
2014	9.9	9.0 – 10.8
2015	10.4	9.5 – 11.4

Table 4 Annual index hospitalisation rate (per 100 000 of age matched Scottish population) of younger adults, 1990 - 2015

Year	Hospitalisation rate	95% CI
1990	3.1	2.5 – 3.8
1991	3.2	2.5 - 3.9
1992	3.6	2.9 - 4.3
1993	3.8	3.1 - 4.5
1994	4.4	3.7 - 5.2
1995	3.8	3.1 - 4.6
1996	5.0	4.2 - 5.9
1997	4.4	3.6 - 5.2
1998	4.5	3.7 - 5.3
1999	4.8	4.0 - 5.3
2000	5.4	4.5 - 6.3
2001	5.5	4.6 - 6.4
2002	7.1	6.1 - 8.1
2003	6.5	5.6 - 7.5
2004	8.4	7.3 - 9.5
2005	9.2	8.1 - 10.4
2006	10.3	9.1 - 11.5
2007	9.6	8.4 - 10.7
2008	11.2	10.0 - 12.4
2009	9.0	7.9 - 10.1
2010	8.1	7.1 - 9.2
2011	8.4	7.3 - 9.4
2012	8.2	7.1 - 9.2
2013	7.9	6.8 - 8.9
2014	7.9	6.9 - 8.9
2015	9.3	8.2 - 10.4

Table 5 Annual index hospitalisation rate (per 100 000 of age matched Scottish population) of those older adults, 1990 - 2015

Year	Hospitalisation rate	95% CI
1990	7.7	6.1 - 9.2
1991	5.0	3.7 - 6.2
1992	6.6	5.1 - 8.0
1993	8.6	7.0 - 10.2
1994	10.0	8.2 - 11.7
1995	8.7	7.1 - 10.4
1996	18.1	15.8 - 20.5
1997	9.8	8.1 - 11.6
1998	5.4	4.1 - 6.6
1999	7.3	5.8 - 8.7
2000	7.0	5.5 - 8.4
2001	7.5	6.0 - 9.0
2002	9.0	7.4 - 10.6
2003	7.1	5.6 - 8.5
2004	8.7	7.1 - 10.3
2005	9.3	7.7 - 11.0
2006	9.2	7.5 - 10.8
2007	12.0	10.2 - 13.9
2008	10.0	8.3 - 11.6
2009	10.2	8.6 -11.9
2010	9.6	8.0 - 11.2
2011	10.8	9.1 - 12.5
2012	9.5	7.9 - 11.1
2013	11.1	9.4 - 12.8
2014	7.9	10.7 - 14.3
2015	9.3	10.5 - 14.0

Table 6 Annual index hospitalisation rate (per 100 000 of age matched Scottish population) of those aged ≥60years old (1990 – 2015), dropping ASD and valvular lesions

Year	Hospitalisation rate	95% CI
1990	6.4	5.0-7.9
1991	4.1	3.0-5.3
1992	5.7	4.3-7.0
1993	6.6	5.2-8.1
1994	8.0	6.4-9.6
1995	7.0	5.5-8.4
1996	13.0	11.0-15.1
1997	5.9	4.6-7.3
1998	2.8	1.8-3.7
1999	2.9	2.0-3.8
2000	3.5	2.5-4.6
2001	3.8	2.7-4.8
2002	3.8	2.8-4.9
2003	3.0	2.0-3.9
2004	4.7	3.5-5.9
2005	3.7	2.6-4.7
2006	4.4	3.3-5.5
2007	5.0	3.8-6.2
2008	5.2	4.0-6.4
2009	4.8	3.7-6.0
2010	6.4	5.1-7.7
2011	5.1	3.9-6.3
2012	4.1	3.0-5.1
2013	4.9	3.8-6.0
2014	6.1	4.8-7.3
2015	4.8	3.7-5.9

Appendix D

Table 1 Summary of baseline characteristics for SIMD quintiles 2-4

	SIMD Quintiles		
	2	**3**	**4**
Hospitalisations, n (%) [p-value]	3 824 (21.4) [<0.05]	3 339 (18.7) [<0.05]	3 019 (16.9) [<0.05]
Adults (≥16)	1 809 (47.3) [<0.05]	1 614 (48.3) [0.07]	1 491 (49.4) [<0.05]
Paediatric (<16)	2 015 (52.7) [<0.05]	1 725 (51.2) [<0.05]	1 528 (50.6) [<0.05]
Median Age, years	26	26	28
Sex, n (%) [p-value]			
Male	1 900 (49.7) [<0.05]	1 690 (50.6) [<0.05]	1 565 (51.8) [<0.05]
Female	1 927 (50.3) [<0.05]	1 649 (49.4) [<0.05]	1 454 (48.2) [<0.05]
Lesion, n (%) [p-value]			
ASD	882 (23.1) [0.05]	757 (22.7) [<0.05]	704 (23.3) [<0.05]
PDA	366 (9.6) [0.10]	287 (8.6) [<0.05]	266 (8.8) [<0.05]
VSD	545 (14.3) [0.06]	468 (14.6) [0.06]	433 (14.3) [<0.05]
AVSD	195 (5.1) [0.06]	161 (4.8) [0.33]	133 (4.4) [<0.05]
Aortic	432 (11.3) [0.06]	399 (11.9) [1.00]	331 (11.0) [<0.05]
Ebstein's	17 (0.4) [0.12]	24 (0.7) [0.96]	26 (0.9) [0.62]
ToF	176 (4.6) [0.06]	151 (4.5) [0.73]	122 (4.0) [<0.05]
TGA	33 (0.9) [0.06]	54 (1.6) [0.10]	33 (1.1) [0.06]
SRV	27 (0.7) [0.53]	22 (0.7) [0.62]	19 (0.6) [0.24]
Fontan	44 (1.2) [0.80]	32 (1.0) [0.07]	26 (0.9) [<0.05]
Valvular	429 (11.2) [0.31]	405 (12.1) [0.73]	390 (12.9) [0.21]
Complex	351 (9.2) [0.06]	312 (9.3) [0.55]	261 (8.6) [<0.05]
Other	330 (8.6) [0.07]	267 (8.0) [0.03]	275 (9.1) [0.10]
Lesion Complexity, n (%) [p-value]			
Mild	1 793 (46.9) [<0.05]	1 512 (45.3) [<0.05]	1 402 (46.4) [<0.05]
Moderate	1 282 (35.5) [<0.05]	1 194 (35.8) [0.70]	1 035 (34.3) [<0.05]
Great	422 (11.0) [0.05]	366 (11.0) [0.23]	306 (10.1) [<0.05]