



Estimating the financial implications of pressure ulcers in private hospitals in South Africa

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Abstract

Quality of care is a concept used to assess the value of healthcare services. Measures of quality of care are important in South Africa given the lack of information on the quality of services delivered in the healthcare sector.

Pressure ulcers are an example of an adverse outcome of a hospital case and indicate poor quality of care. The financial implications of this event therefore represent an estimate of the cost of poor quality of care.

The objective of this research is to estimate the financial implications of pressure ulcers in private hospitals in South Africa on a risk-adjusted basis. Pressure ulcers are identified using administrative data from medical schemes. Statistical modelling and statistical tests are used to create risk cells so that comparisons are done on a like-for-like basis.

The results indicate that the average financial implications for a hospital case where an individual is diagnosed with a pressure ulcer, on a risk-adjusted and weighted basis, is 3.3 times the average financial implications for a hospital case where an individual is not diagnosed with a pressure ulcer. The impact of this event on the medical scheme industry is estimated at R1.4 billion.

Identifying hospital cases where an individual is diagnosed with a pressure ulcer is limited because the data are used for reimbursement and case management. The financial implications could have been affected by additional factors not available in the data. Pressure ulcers result in non-financial implications for the individuals receiving and delivering healthcare services. These are not quantified in this research. Pressure ulcers are only one measure amongst many metrics that can be used to assess quality of care.

Private hospitals can use a measure of pressure ulcers to quantify the quality of their healthcare services. Managed care organisations can therefore use these results to create a network of hospitals and they can use these results when negotiating with hospitals on the amount that they will reimburse them for the services that they provide.

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Chapter 1

Introduction

The main objective of this research is to estimate the financial implications of pressure ulcers in private hospitals in South Africa on a risk-adjusted basis from the perspective of medical schemes. Public hospitals are not considered in this research because there are an insufficient volume of accurate data available (Ramjee, 2013). Pressure ulcers are considered as an outcome measure of quality of care relating to adverse events in hospitals in this research (Slawomirski, Auraaen and Klazinga, 2017). The incidence of pressure ulcers is a single metric amongst the many measures that can be used to assess quality of care in hospitals (Agency for Healthcare Research and Quality, 2015). The financial implications of pressure ulcers therefore only represent a proportion of the total cost of poor quality of care. This research, however, is important because it provides an estimate of the cost of poor quality of care.

Private hospitals in South Africa are currently not required to report on the quality of care in their hospitals (Still, 2016). This lack of public information, however, has been highlighted and there is a need for hospitals to provide this information (Medical Brief, 2015; Bateman, 2017; Health Market Inquiry, 2017). This research provides a measure that hospitals can use to report on the quality of care in their hospitals.

Managed care organisations, in South Africa, are concerned with both the cost and quality aspects of healthcare services (Health Market Inquiry,

2018). They could therefore use the estimate of the financial implications of pressure ulcers as a measure of poor quality of care. Given this, they could establish a network of hospitals with the lowest incidence of pressure ulcers (Health Market Inquiry, 2018). They could use this financial estimate when negotiating with hospitals on the amount that they will reimburse them for the services that they provide (Health Market Inquiry, 2018). The cost of preventing pressure ulcers, however, will also need to be considered. This research will therefore help managed care organisations to meet their aim of delivering cost-effective and high quality healthcare services (Health Market Inquiry, 2018). Pressure ulcers are only one metric amongst many measures and managed care organisations should therefore also consider other measures (Agency for Healthcare Research and Quality, 2015).

There are three sub-objectives that are used to meet the main objective. The first sub-objective is to identify hospital cases where the individual is diagnosed with a pressure ulcer. The second sub-objective is to use statistical modelling to identify the factors that can explain the variation in the financial implications for a hospital case. The third sub-objective is to calculate the financial implications of hospital cases where an individual is diagnosed with a pressure ulcer. This is compared to the financial implications of otherwise similar hospital cases where an individual is not diagnosed with a pressure ulcer by considering the relevant risk-adjustment factors that are identified. The financial implications are viewed from the perspective of the administrator of a medical scheme and therefore the amount paid for all services and medical goods over the period of the hospital case is considered (Actuarial Society of South Africa, 2017d). This total amount is referred to as the benefit paid for a hospital case.

The benefit paid for a hospital case varies as a result of the attributes of each individual (Iezzoni, 2012). Statistical modelling is used to identify these factors to create risk cells (Duncan, 2011). Statistical tests are also used given the limited results of the models. This ensures that comparisons are done on a like-for-like basis and that the difference in the benefit paid between a

hospital case where an individual is diagnosed with a pressure ulcer compared to a hospital case where an individual is not diagnosed with a pressure ulcer is driven by the diagnosis of the pressure ulcer (Iezzoni, 2012). The results in this research are therefore expressed on a risk-adjusted basis. For example, the age and sex of an individual is likely to influence the benefit paid for a hospital case (Duncan, 2011).

Chapter 2 provides context to this research by describing hospitals and medical schemes in South Africa. A description of the current systems that are used to measure quality of care in South Africa in this chapter highlights the importance of this research. Quality of care frameworks and dimensions are covered in Chapter 3. Pressure ulcers as an example of an adverse event and a measure of quality of care are described in this chapter. A background on risk adjustment is also provided in this chapter. Chapter 4 describes the raw data that are used, the available variables and the data-cleaning process that is followed. Chapter 5 outlines the methodology that is followed. This includes a description of the adjustments applied to the linked dataset, the methodology underlying the statistical modelling process for risk adjustment and the application of risk adjustment. Chapter 6 presents the final results and Chapter 7 discusses the research and provides a conclusion.

This research covers private hospital cases in South Africa over the period from 1 January 2014 to 30 September 2017 using administrative data from medical schemes in South Africa. This research assumes that the administrative data that are used are accurate. This accuracy is therefore limited by the quality of the information provided by the individuals that receive healthcare services and the individuals that deliver healthcare services in private hospitals¹. The detail in the data are limited by the information that is captured for case management and reimbursement purposes (Actuarial Society of South Africa, 2017d,a).

¹L Whitelaw 2018, personal communication, 28 August.

Chapter 2

Background

2.1 Hospitals in South Africa

The South African hospital environment includes hospitals in the public sector and the private sector that deliver healthcare services to the South African population (Coovadia, Jewkes, Barron, Sanders and McIntyre, 2009).

Hospitals in the public sector are owned by the government and run on a not-for-profit basis (Ramjee, 2013). The types of hospitals in this sector include: district hospitals, regional hospitals and central hospitals (Ramjee, 2013). The estimate of expenditure on hospitals in the public sector at the end of the 2016 financial period was R129.2 billion (National Treasury, 2016).

The hospitals that are privately owned are primarily owned by three large hospital groups¹that accounted for approximately 80% of in-patient beds in 2015 (Health Market Inquiry, 2018). These hospital groups are listed on the Johannesburg Stock Exchange and are therefore run on a for-profit basis to meet the needs of shareholders (Health Market Inquiry, 2018). The other hospitals include the National Hospital Network (NHN) and other smaller independent hospital groups, namely Clinix Health Group Ltd and Joint

¹A hospital group is formed when one company owns several hospitals (Willie and Matsebula, 2007).

Medical Holdings (Health Market Inquiry, 2018). The NHN is a group of independent and privately owned hospitals (Health Market Inquiry, 2018).

The majority of private hospitals are classified as short-stay hospitals where individuals are admitted for less than 30 days (Willie and Matsebula, 2007). These hospitals mainly provide services to individuals who belong to medical schemes, as described in section 2.2 (Willie and Matsebula, 2007). The expenditure on private hospitals by medical schemes for the 2015 financial period was R48.5 billion (Council for Medical Schemes, 2016). The cost of healthcare services varies according to the sector and it is therefore difficult to compare costs between the public and the private sector (Ramjee, 2013).

There is an insufficient volume of accurate data available in the public sector and it is therefore difficult to assess the quality of care provided by public hospitals (Ramjee, 2013). This research therefore uses data covering private hospitals in South Africa.

2.2 Medical schemes in South Africa

Medical schemes are the most common form of healthcare financing in the private healthcare sector in South Africa (Health Market Inquiry, 2018). They give individuals the ability to access private healthcare services (Smith and Burger, 2013). Medical schemes provide products similar to those provided by medical insurance (McLeod and Ramjee, 2007).

The Medical Schemes Act (MSA) no. 131 of 1998 prescribes the legal framework for medical schemes (Health Market Inquiry, 2018). The MSA indicates that medical schemes must have open enrolment and that contributions need to be community-rated (Department of Health, 1998). The provision of mandatory minimum benefits has been enforced since 2000 when the MSA came into effect (van den Heever, 2012).

Medical schemes accept monthly contributions from the individuals who belong to their scheme and provide financing for healthcare services through a package of benefits (Health Market Inquiry, 2018). A medical scheme can

have more than one benefit option where these vary according to the package of benefits offered (McLeod and Ramjee, 2007). The mandatory minimum benefits, however, must be covered by all options (McLeod and Ramjee, 2007). The focus of these benefits is to provide cover for care delivered in hospitals (Kaplan and Ranchod, 2015).

According to a report published by the Council for Medical Schemes, there were approximately 8.8 million individuals registered as belonging to a medical scheme as at 31 December 2015 (Council for Medical Schemes, 2016). This is approximately 16% of the population of South Africa (Johnson, Chiu, Myer, Davies, Dorrington, Bekker, Boulle and Meyer-Rath, 2016). The majority of medical scheme membership is as a result of employers offering this as a benefit to their employees (Smith and Burger, 2013).

Administrators provide administrative services to medical schemes (Health Market Inquiry, 2018). They manage the day-to-day operations of a medical scheme by collecting contributions from individuals and making payments to individuals who provide healthcare services (Health Market Inquiry, 2018). They also manage records of the individuals who belong to their scheme, provide financial reports and implement data control measures (Health Market Inquiry, 2018).

Managed care organisations offer managed care services to medical schemes (Health Market Inquiry, 2018). They aim to deliver cost-effective and high quality healthcare services to the individuals who belong to the medical scheme (Health Market Inquiry, 2018). They do this by using clinical, statistical and financial techniques to control risks, manage costs and improve the quality of care provided (Actuarial Society of South Africa, 2017a). This includes using specific networks of healthcare service providers (Health Market Inquiry, 2018). They can also negotiate with these providers for the amount that they will reimburse them for their services (Actuarial Society of South Africa, 2017a).

Data from both administrators and managed care organisations, but collected by the administrator, are used in this research.

2.3 Quality of care in South African hospitals

The quality of healthcare services provided by public and private hospitals in South Africa is under scrutiny (Medical Brief, 2015; Bateman, 2017). The recent Health Market Inquiry (HMI) led by the Competition Commission highlighted that there is a lack of information on the quality of care in the healthcare sector (Still, 2016). A document released by the HMI stated that there is insufficient “relevant, timely and validated information” to be able to assess quality of care (Health Market Inquiry, 2017:pg.2). There is neither a legislative requirement for hospitals to report on quality of care nor is there a standardised system for them to report this information (Willie and Matsebula, 2007).

The Office of Health Standards Compliance was established in 2003 under the National Health Act (NHA) to ensure the safety and quality of healthcare environments for all South Africans (Office of Health Standards Compliance, 2016). Their functions are defined in the NHA (Office of Health Standards Compliance, 2014). They have developed National Core Standards as the minimum standards for healthcare establishments (Ranchod, Adams, Burger, Carvounes, Dreyer, Smith, Stewart and Van Biljon, 2017). They conduct inspections to assess the structure and processes of hospitals (Kahn, 2016). Their role in the private sector has been questioned by many stakeholders (Health Market Inquiry, 2017). There is no sector regulator in the private sector (Health Market Inquiry, 2018).

The South African government acknowledges that there are problems relating to the quality of care provided by public hospitals, including long waiting times and poor infection control (Department of Health, 2015).

The structure and processes of some public and private hospitals are assessed by the Council for Health Service Accreditation of Southern Africa (COHSASA) (Ranchod *et al.*, 2017). COHSASA was registered in 2005 as a not-for-profit organisation with the aim of implementing quality improvement and accreditation for hospitals in South Africa (Whittaker, Shaw, Spieker and Linegar, 2011). The components of COHSASA are accredited by the

International Society for Quality in Healthcare². Hospitals voluntarily apply for this assessment because it is not required by legislation (Ranchod *et al.*, 2017). These results allow the hospitals to identify areas for improvement². Results of these scores from 2001 - 2014 indicate that the average score for hospitals in the private sector is higher than the average score for hospitals in the public sector at the 5% level of significance (Ranchod *et al.*, 2017). These results also indicate that there is less variation of scores within the private sector compared to the public sector (Ranchod *et al.*, 2017).

Research to further this is not possible given the data constraints in the public sector (Ramjee, 2013). Data for private sector hospitals are available but the research using the COHSASA scores only includes 35 hospitals in the private sector. Additional results for these hospitals would not be credible given the low number of private hospitals included in the research (The Actuarial Education Company, 2017b). Even if the data from the public sector are available, the financing of healthcare resources varies between the public and the private sector (Ramjee, 2013). This affects the number of resources available and therefore comparisons across the two sectors is difficult.

There are also difficulties of using process measures to assess quality of care. These measures need to be assessed relative to guidelines (Mainz, 2003). This assessment requires clinical expertise and is therefore not in the scope of this research. Research relating to the dimension of structure and processes in South African hospitals is therefore not done in this research.

The three large hospital groups (Life Healthcare, Mediclinic Southern Africa and Netcare) publish annual reports that include quality of care reports (Life Group, 2017; Mediclinic, 2018; Netcare Limited, 2016). These reports include outcome measures such as rates of: catheter-associated urinary tract infections, central-line-associated bloodstream infections, ventilator-associated pneumonia, surgical site infections, falls and pressure ulcers (Life Group, 2017; Mediclinic, 2018; Netcare Limited, 2016). Measures of medication errors have

²C Adams and J Stewart 2016, personal communication, 1 June

also been included (Life Group, 2017; Mediclinic, 2018; Netcare Limited, 2016). A number of factors should be considered when comparing these results.

The hospital groups do not report on these measures in every annual report. It is therefore difficult to assess the performance of the hospital groups over time. The hospital groups do not include the technical definitions used to calculate the values that are included in their reports. It is therefore difficult to compare the results across hospital groups. Two measures, namely catheter-associated urinary tract infections and surgical site infection were reported across the three hospital groups in 2015 and 2016. It is, however, not possible to draw conclusions from these results given the issues that need to be considered. The data used to report on these measures are not available and these results have therefore not been included.

Discovery Health, the administrator of Discovery Health medical scheme, launched a hospital ranking index that includes measures of complications, re-admissions and mortality (Bateman, 2006). They withdrew the results, however, because their methodology was questioned (Medical Brief, 2015). The issues raised included: the methodology had flawed risk adjustment, the outcomes were perceived by the public to be clinical but were derived from financial and administrative data and the concern that the results could damage the relationship between the individual delivering healthcare services and the individual receiving healthcare services (Bateman, 2006). Risk adjustment is therefore an important consideration in this research.

Discovery Health also initiated a patient experience survey for use by individuals who belong to Discovery Health medical scheme (Discovery Holdings, 2015). This is adapted from the Hospital Consumer Assessment of Healthcare Providers and Systems developed by AHRQ (Discovery Holdings, 2015). It was conducted amongst adults at the end of their hospital case (Discovery Holdings, 2015). The survey uses risk-adjustment methods by considering the age, sex and nature of illness of the individuals (Discovery Holdings, 2015). These factors are considered in this research for risk adjustment, as explained in section 5.3.3.

Chapter 3

Literature review

3.1 Introduction

Quality of care is a concept that is used to assess the value of healthcare services (Donabedian, 2005). Figure 3.1 provides an outline of the structure followed in this research to quantify this concept.

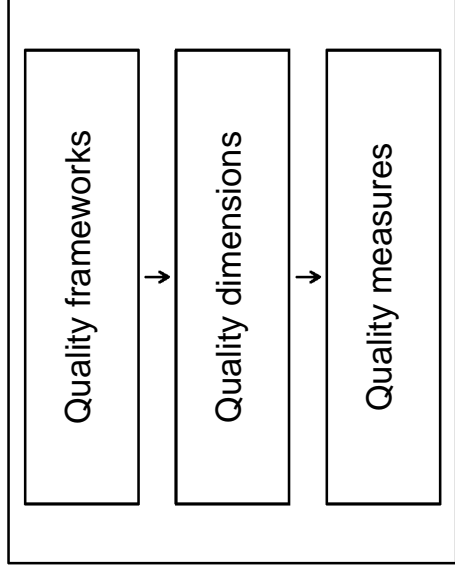


Figure 3.1: Structure followed to quantify quality of care

There are two frameworks referred to in this research that can be used to assess the quality of care in private hospitals. These frameworks propose specific dimensions that should be considered when assessing the quality of the healthcare services delivered. In this research, the dimension of outcomes is used to assess the quality of care in private hospitals (Donabedian, 2005; Porter, 2010). The frameworks that include this dimension are described in section 3.2. An adverse event that occurs during the period of the hospital case reflects an event that occurs after an individual has received healthcare services and is therefore an outcome of the hospital case (Mainz, 2003). These are described in section 3.3. This section describes sources that can be used to identify measures of these events. Specifically, the incidence of pressure ulcers is used as an adverse event measure (Agency for Healthcare Research and Quality, 2018b). A detailed description of pressure ulcers and the reasons for choosing pressure ulcers is described in section 3.4. The importance of risk adjustment in this research is described in section 3.5.

3.2 Frameworks and dimensions of quality of care

The two frameworks referred to in this research are those proposed by Avedis Donabedian and Michael Porter. Donabedian considers structure, process and outcome dimensions to be important when assessing the quality of care in a healthcare environment (Donabedian, 2005). Porter considers the dimension of outcomes to be important when assessing quality of care (Porter, 2010). Both frameworks therefore consider outcomes to be important when assessing quality of care (Donabedian, 2005; Porter, 2010).

Outcomes can be defined as the state of health or events that follow after an individual has received healthcare services (Mainz, 2003). There are many measures that can be used to quantify the dimension of outcomes. Traditional outcome measures include mortality and physiological measures (Clancy and Eisenberg, 1998). Other outcome measures relate to discomfort, disability

and dissatisfaction (Mainz, 2003). These measures could include, for example, an evaluation of the individual's experience of care (BMJ Outcomes, 2015b).

A broad measure would include the outcomes of a hospital and a narrow measure would include the outcomes of a single department (Porter, 2010). The pressure ulcer rate of a department in a hospital, for example, could be considered as an example of a narrow outcome measure used to quantify the quality of care in that department.

The renewed focus of healthcare on the needs of the individual has resulted in the development of patient-reported measures (Berg, 2015; BMJ Outcomes, 2015b). These report on outcomes from the perspective of the individual (Baumhauer and Bozic, 2016). Examples of these measures include: the individual's perception of health, functional measures and patient satisfaction (Clancy and Eisenberg, 1998). An electronic system to record the physical, mental and social health of individuals was developed as a result of an initiative by the National Institute of Health in the United States of America (Baumhauer and Bozic, 2016). In the Netherlands, individuals can post online reviews of hospitals on a system called the "Zorgkaart Nederlands" (BMJ Outcomes, 2015a).

Donabedian highlights that outcome measures are generally accepted as valid measures to quantify quality of care (Donabedian, 2005). He refers to the concept of risk adjustment by indicating that outcome measures are affected by many factors and that these should be held constant before conclusions are drawn from these measures (Donabedian, 2005). Risk adjustment is therefore important when considering outcome measures.

Porter only considers the dimension of outcomes and proposes that value should be considered as the "health outcomes achieved per dollar spent" (Porter, 2010:pg.2477). He explains that the measures chosen should be considered from the perspective of the individual receiving healthcare services in the healthcare environment (Porter, 2010). He suggests that outcome measures should consider both the near term and longer term health of the individual (Porter, 2010). Porter echoes the concept of risk adjustment

referred to by Donabedian by suggesting that initial conditions and other factors should be considered when evaluating these outcome measures (Porter, 2010). Risk adjustment is therefore considered in this research to allow for meaningful comparisons (Rubin, Pronovost and Diette, 2001).

Porter adds that the value of healthcare services is often only observed over a longer period of time given that a number of individuals play a role in delivering healthcare services for the individual. He therefore suggests that it would be ideal to measure both the costs and outcomes for each individual longitudinally (Porter, 2010).

There are difficulties that need to be considered when measuring outcomes. Measures of outcomes are seldom collected as part of a routine data collection process (Lawson, Zingmond, Lee Hall, Louie and Ko, 2015). A long period of time might need to pass before the relevant outcome data are available (Donabedian, 2005). Developing risk-adjustment models to allow for meaningful comparisons of outcome measures is analytically complex, requires statistical expertise and a large number of individuals to develop the process (Rubin *et al.*, 2001).

There are, however, advantages to using outcome measures. The definition of these measures is usually more amenable to being precise and can therefore be easily measured (Donabedian, 2005). They create a feedback process where the individual who provides healthcare services is able to review their performance by evaluating their outcome measures (Dale, Myint and Compton-Phillips, 2016). Outcomes can be considered as the most important dimension to measure because these measures are the actual results of the healthcare services delivered to the individual (Donabedian, 2005; Porter, 2010).

The other dimensions considered by Donabedian include: structure and process (Donabedian, 2005). These can serve as alternative dimensions to assess the quality of care given the difficulties of using the dimension of outcomes (Rubin *et al.*, 2001; Mainz, 2003).

The structure dimension of a healthcare system determines the extent to which it is able to meet the needs of the individuals entering the system

(Mainz, 2003). Specifically, this is the type and amount of resources available within the system (Mainz, 2003). Examples of measures of this dimension include: number of staff, beds and buildings and the amount of money and supplies available (Mainz, 2003). The structure of a hospital can be formally measured through accreditation (Brubakk, Vist, Bukholm, Barach and Tjomsland, 2015). Accreditation involves assessing the structure of a hospital against prescribed standards (Brubakk *et al.*, 2015).

The process dimension can be considered as the set of inputs, activities and outputs used to deliver the healthcare services (Yildiz, Demirörs, Yildiz and Demirors, 2013). Process measures assess what the individual who provided healthcare services did and how well they did this (Mainz, 2003). The individual would be assessed relative to the guidelines specified for this process (Mainz, 2003). A laboratory process is a practical example of a process in a hospital (Yildiz *et al.*, 2013). In this process, the request forms are an example of an input, taking a blood sample is an example of an activity and the approved laboratory results is an example of an output (Yildiz *et al.*, 2013).

Measures of outcome, structure and process dimensions could be assessed against either empirical or normative standards (Donabedian, 2005). Empirical standards could, for example, involve comparing the results of two hospitals with each other and assessing their relative performance (Donabedian, 2005). The assessment of the measures against normative standards would involve using external data sources as a comparison (Donabedian, 2005).

Outcomes are used as the dimension to assess quality of care in this research because these can be considered as the results of the healthcare services delivered to the individual (Porter, 2010; Donabedian, 2005). The data are available to develop a risk-adjustment model (Mainz, 2003). Adverse events are used as an outcome measure of the events that follow after an individual has received healthcare services. Information in the data can be used to identify these events.

3.3 Adverse events as an outcome measure

Adverse events are included in the broader classification of patient harm that includes measures of both complications and adverse events (Slawomirski *et al.*, 2017). Patient harm is considered as any unintended or unnecessary consequence that results from or is contributed to from the healthcare environment (Slawomirski *et al.*, 2017). The probability of a complication occurring when delivering healthcare services always exists (Slawomirski *et al.*, 2017). Adverse events are considered to be largely preventable (Slawomirski *et al.*, 2017). These are therefore used in this research as a measure of quality of care because these should, in most cases, never occur in hospitals (Slawomirski *et al.*, 2017).

The Organisation for Economic Co-operation and Development (OECD) estimates that treating adverse events accounts for approximately 15% of hospital expenditure and activity in OECD countries (Slawomirski *et al.*, 2017). The most burdensome events include: healthcare-associated infections, venous thrombo-embolism, pressure ulcers, medication errors and wrong or delayed diagnosis (Slawomirski *et al.*, 2017). The OECD estimates that the costs of preventing these events are often lower than the costs of the adverse events occurring (Slawomirski *et al.*, 2017).

The government in the United States of America has recognised the importance of minimising the number of adverse events in hospitals (Zhan, Elixhauser, Richards, Wang, Baine, Pineau, Verzier, Klimanand and Hunt, 2009). They have passed legislation to penalise hospitals where individuals develop hospital-acquired conditions (Zhan *et al.*, 2009). Hospitals will receive payment based on the diagnosis of the individual (Porter and Teisberg, 2006). These hospitals will not receive additional payment for hospital cases where an individual develops a hospital-acquired condition, such as a catheter associated urinary tract infection, to pay for the additional resources needed to treat the hospital-acquired condition (Zhan *et al.*, 2009).

There are a number of different sources that can be used to identify measures of adverse events. The OECD currently collects data on five patient

safety measures (Organisation for Economic Co-operation and Development, 2018). The Agency for Healthcare Research and Quality (AHRQ) currently has 18 patient safety indicators (PSIs) (Agency for Healthcare Research and Quality, 2018b). Private hospitals in South Africa include measures of adverse events in their annual reports (Life Group, 2017; Mediclinic, 2018; Netcare Limited, 2016). These measures are relevant in a South African context given that these hospitals collect this data.

A measure of pressure ulcers is included in the AHRQ PSIs and in the annual reports published by private hospitals in South Africa (Life Group, 2017; Mediclinic, 2018; Netcare Limited, 2016; Agency for Healthcare Research and Quality, 2018b). The methodology used to identify pressure ulcers in administrative data is possible given the data that are available in this research (Quan, Drosler, Sundararajan, Wen, Burnand, Couris, Halfon, Januel, Kelley, Klazinga, Luthi, Moskal, Pradat, Romano, Shepherd, So, Sundaresan, Tournay-Lewis, Trombert-Paviot, Webster and Ghali, 2008). An assessment of the financial implications of this adverse event is therefore possible to do and is relevant in a South African context.

3.4 Pressure ulcers as an example of an adverse event

A pressure ulcer is a “localised injury to the skin and/or underlying tissue usually over a bony prominence, as a result of pressure, or pressure in combination with shear” (National Pressure Ulcer Advisory Panel, European Pressure Ulcer Advisory Panel and Pan Pacific Pressure Injury Alliance, 2014:pg.12). There are four stages of pressure ulcers and these are classified according to the depth of the ulcer (National Pressure Ulcer Advisory Panel *et al.*, 2014). The first stage is described as “nonblanchable erythema” and the fourth stage is described as “full thickness tissue loss” (National Pressure Ulcer Advisory Panel *et al.*, 2014:pg.12-13). Other pressure ulcers are classified as “unstageable” if the depth is unknown (National Pressure Ulcer Advisory

Panel *et al.*, 2014:pg.13).

There are groups of individuals that are more likely to develop pressure ulcers (Russo, Steiner and Spector, 2008). These include: the elderly, stroke victims, individuals with dementia and individuals with impaired mobility and sensation such as those who use wheelchairs or are bedridden (Russo *et al.*, 2008). These individuals have limited mobility and are therefore more likely to develop pressure ulcers (Perneger, Gaspoz, Raë, Borst and Hélot, 1998).

AHRQ has developed a measure of pressure ulcers in hospitals to assess the performance of hospitals (Agency for Healthcare Research and Quality, 2006). AHRQ recognises the groups of individuals that are more likely to develop pressure ulcers and these groups are therefore excluded from this measure (Agency for Healthcare Research and Quality, 2006). Specifically, they exclude cases where the individual has hemiplegia, paraplegia, quadriplegia, spina bifida or anoxic brain damage (Agency for Healthcare Research and Quality, 2006). These individuals are excluded because it is not fair to assess the relative performance of a hospital that treats individuals that are more likely to develop pressure ulcers. In this research, these hospital cases are identified using diagnosis codes from the administrative data. These hospital cases are referred to as the AHRQ-exclusion hospital cases and an indicator variable is created to identify these hospital cases. These hospital cases are not excluded because the objective of this research does not include assessing the performance of individual hospitals.

The incidence of pressure ulcers in healthcare environments is varied. An analysis of approximately 1.8 million hospital cases in the English National Health System (NHS) showed an incidence rate of 7.8 cases of pressure ulcers per 1 000 hospital cases (Bottle and Aylin, 2009). The results of a nation-wide pressure ulcer survey in Germany and the Netherlands showed the number of individuals with at least one pressure ulcer per 100 individuals at risk of developing a pressure ulcer (Tannen, Dassen and Halfens, 2008). The results have been stratified to account for the risk of developing a pressure ulcer, as

defined by the Braden scale, where Group 3 has the greatest likelihood of developing a pressure ulcer (Tannen *et al.*, 2008). These results are shown in Table 3.1.

Table 3.1: Incidence of pressure ulcers per 100 individuals at risk of developing a pressure ulcer

	Dutch nursing homes	German nursing homes	Dutch hospitals	German hospitals
All cases	31	6	18	9
Group 1	37	9	28	18
Group 2	40	11	35	24
Group 3	43	13	41	29

There are statistically significant differences in the incidence of pressure ulcers between Germany and the Netherlands (Tannen *et al.*, 2008). Some of these differences can be explained by the underlying population and the higher level of prevention measures in Germany (Tannen *et al.*, 2008). The differences between the two studies might also be as a result of different definitions or different systems to report on these measures.

It is difficult to compare the results in the annual reports of the South African private hospitals. Mediclinic included the in-hospital pressure ulcer rate per 1 000 patient days (Mediclinic, 2018). Life Healthcare included the incidence of pressure ulcers but combined these results with other adverse events (Life Group, 2017). Netcare highlights that they aim to prevent patient harm, including the incidence of pressure ulcers, but do not include the figures to illustrate the incidence of pressure ulcers (Netcare Limited, 2016).

The variation in both the international and local results of the incidence of pressure ulcers highlights the importance of the standardisation of information in data so that these events can be accurately identified.

Pressure ulcers cause pain and can result in a longer length of stay (Institute for Healthcare Improvement, 2017). More severe cases of pressure ulcers may lead to sepsis or may result in death (Institute for Healthcare Improvement, 2017). The study in the English NHS showed that the in-hospital death rate of those who were flagged as having a pressure ulcer was more than four times higher compared to the other hospital cases (Bottle and Aylin, 2009). The upper quartile of the length of stay of these individuals increased from 18 days to 50 days (Bottle and Aylin, 2009). This comparison is done after accounting for the age and sex of the individuals to ensure that valid comparisons are made (Bottle and Aylin, 2009). Other factors, however, such as the family history of these individuals or their existing medical conditions could have influenced these results and should therefore be considered (Duncan, 2011). Age and sex are therefore considered as factors for risk adjustment in this research. Other factors are also used to ensure that relevant comparisons are made. These are explained in further detail in section 5.3.3. This burden of pain, suffering and decreased quality-of-life should be considered as a non-financial cost of pressure ulcers for the individual receiving healthcare services (Brem, Maggi, Nierman, Rolnitzky, Bell, Rennert, Golinko, Yan, Lyder and Vladeck, 2011).

The individuals who deliver healthcare services at the hospital are also affected by the incidence of a pressure ulcer (Seys, Wu, Gerven, Vleugels, Euwema, Panella, Scott, Conway, Sermeus and Vanhaecht, 2013; Wu and Steckelberg, 2012). These individuals may experience many emotions including: guilt, anger or frustration because they were involved in a hospital case where there was an adverse event (Seys *et al.*, 2013; Wu and Steckelberg, 2012). In some cases, individuals may develop post-traumatic stress disorder (Seys *et al.*, 2013). These can be considered as additional non-financial implications of an individual developing a pressure ulcer at hospital.

International studies show that a pressure ulcer can more than double the cost of a hospital case (Russo *et al.*, 2008; Allman, Goode, Burst, Bartolucci and Thomas, 1999). The total cost of pressure ulcers was estimated at 4%

of the total English NHS expenditure in 2000 (Bennett, Dealey and Posnett, 2004).

Pressure ulcers are considered as serious reportable adverse events and are preventable (National Quality Forum (NQF), 2011; Black, Edsberg, Baharestani, Langemo, Goldberg, McNichol and Cuddigan, 2011). There are a number of methods that can be used to prevent the incidence of pressure ulcers. These methods include the purchase of items as well as a change in the healthcare services provided. These items include pressure-reducing support surfaces that can be used to redistribute pressure (National Pressure Ulcer Advisory Panel, 2007; Tannen *et al.*, 2008). For example, mattresses with specific functions, such as the function to rotate the individual so as to relieve pressure on the bony prominence of their body, can be purchased (National Pressure Ulcer Advisory Panel, 2007). A change in the healthcare services delivered can also be used to prevent the incidence of a pressure ulcer. The individual should be positioned with particular attention to the tissue overlying their bony prominences and they should be repositioned regularly (Reddy, Gill and Rochon, 2006). This should help to relieve the pressure on the bony prominences of their body (Reddy *et al.*, 2006). The skin of the individual should be assessed regularly and their skin should be kept clean and dry (National Pressure Ulcer Advisory Panel *et al.*, 2014; Institute for Healthcare Improvement, 2017).

Pressure ulcers are used in this research as an example of an adverse event measure to estimate the financial implications of poor quality of care. There are many measures that can be implemented to prevent the incidence of pressure ulcers and they are therefore a measure of the poor quality of healthcare services in hospitals (National Quality Forum (NQF), 2011; Black *et al.*, 2011). They are recognised by AHRQ as one of their patient safety measures and the importance of reducing the incidence of pressure ulcers is recognised in the annual reports published by South African private hospitals (Life Group, 2017; Mediclinic, 2018; Netcare Limited, 2016; Agency for Healthcare Research and Quality, 2018a). They are recognised by the

OECD as one of the most burdensome events and result in both financial and non-financial implications for the individual receiving healthcare services and the individual delivering healthcare services (Slawomirski *et al.*, 2017). They are also identifiable using the data available for this research (Agency for Healthcare Research and Quality, 2006; Quan *et al.*, 2008). It is therefore possible to use pressure ulcers as an adverse event measure.

Risk adjustment is used in this research because there is variation in the financial implications of a hospital case that can be attributed to the risk profile of the individual and not to the diagnosis of a pressure ulcer (Duncan, 2011). These are accounted for when risk adjustment is used and ensures that these do not confound the results (Iezzoni, 2012; Duncan, 2011).

3.5 Overview of risk adjustment

Risk adjustment is a concept that, when applied, allows for meaningful comparisons between groups of individuals with different risk profiles (Duncan, 2011). Risk adjustment is used in many different areas including: measuring healthcare outcomes and efficiency, budgeting, risk management and provider profiling (The Actuarial Education Company, 2017a).

Risk adjustment can be applied using a number of methods including: statistical modelling, groupers or propensity scores (The Actuarial Education Company, 2017a; Iezzoni, 2012).

A statistical model, generally, is used to explain the relationship between the response variable and the explanatory variables (Dobson and Barnett, 2008). These relationships can be used in the methodology to apply risk adjustment by grouping individuals that are statistically homogeneous with respect to the response variable, based on the results from the statistical modelling process (Insight Actuaries and Consultants, 2016). These factors are identified using data from the individuals in the statistical modelling process and are therefore relevant to these individuals. Statistical modelling, however, requires a large number of hospital cases (Rubin *et al.*, 2001).

There are a number of groupers that are available. Groupers are defined algorithms that are used to identify the clinical conditions of individuals (Duncan, 2011). These are usually commercial models where the predictive accuracy of these models is usually studied extensively (Duncan, 2011). Episode groupers, for example, use administrative data and group the claims that are submitted into a clinical episode (Thomas, Caplan, Levy, Cohen, Leonard, Caldis and Mueller, 2010). A diagnosis related grouper (DRG) is a grouper that was developed to evaluate the outcomes of hospital cases (Iezzoni, 2012). A DRG allows for meaningful analysis of outcomes because hospital cases are classified into clinically intuitive and homogeneous classifications where each hospital case within a classification is expected to have a similar use of healthcare resources (Insight Actuaries and Consultants, 2016). In South Africa, profiling and risk assessment in a hospital is one of the uses of DRGs (Actuarial Society of South Africa, 2017d).

A propensity score as a methodology to risk-adjust the results is usually used in observational studies where there is an intervention (Iezzoni, 2012). This method is used to reduce bias when estimating the effectiveness of an intervention (Huang, Frangakis, Dominici, Diette and Wu, 2005). A propensity score is calculated for each individual using a logistic regression model (Iezzoni, 2012). This score is used as a measure of the risk profile of an individual and can therefore account for several factors that affect the risk profile of an individual given the nature of the statistical model (Dehejia and Wahba, 2002). Comparisons are done on the effectiveness of the intervention between individuals with a similar propensity score (Iezzoni, 2012).

Statistical modelling is used in this research and this is described in section 5.3. The results from a DRG are used in the statistical modelling process because this summarises the clinical information of a hospital case. Section 5.4 provides a detailed outline of the methodology to apply risk adjustment using the results from the statistical models. Statistical tests are also used in this methodology given the limited results of the statistical models.

Chapter 4

Data

4.1 Description of the data

Private hospitals are, to a large extent, reimbursed on a system based on fee-for-service (Willie and Matsebula, 2007). Detailed administrative data are therefore collected by the administrator for reimbursement purposes (Health Market Inquiry, 2018). The function of the managed care organisation includes the pre-authorisation and management of hospital cases and they therefore collect data for this purpose (Actuarial Society of South Africa, 2017d,a). Data from both the administrator and the managed care organisation are therefore used in this research.

Data from individuals representing approximately 24% of the medical scheme industry in South Africa are used in this research (Council for Medical Schemes, 2016). The data covers three medical schemes and 25 benefit options. This data were provided by Insight Actuaries and Consultants. Three datasets are used to create a linked dataset.

The first dataset includes hospital cases identified by a pre-authorisation number at private hospitals (practice code 057/058) with an admission date within the period from 1 January 2014 to 30 September 2017 (Health Market Inquiry, 2018). Data over multiple years ensures that there are a sufficient volume of data so that the results are credible (The Actuarial Education

Company, 2017b). A more up-to-date dataset is not used to ensure that claims are fully run-off so that all claims submitted by the individual over the period of the hospital case are included (Actuarial Society of South Africa, 2017b). This dataset includes clinical information and administrative information for each hospital case. The clinical information includes diagnosis and procedure codes (Actuarial Society of South Africa, 2017d). Administrative information are: a unique identifier for the hospital, the date when the individual is admitted to hospital and the date when they are discharged from hospital (Actuarial Society of South Africa, 2017d).

The second dataset includes claims submitted to the administrator over the period of the hospital case (Health Market Inquiry, 2018). All fees charged by individuals who provide healthcare services and all pharmaceuticals and surgical and healthcare consumables used over the period of the hospital case result in a claim being submitted to the administrator (Actuarial Society of South Africa, 2017d). The schemes used in this research provide reimbursement based on a fee for each service and therefore more than one claim will be submitted for each hospital case given the nature of medical schemes in South Africa (Willie and Matsebula, 2007). Each claim submitted describes administrative information including: the rand amount claimed for each medical service or good over the period of the hospital case and the amount that the administrator reimburses for these claims (Actuarial Society of South Africa, 2017d). The amount that the administrator reimburses for these claims is used in this research. The total amount paid for all claims submitted over the period of the hospital case is referred to as the benefit paid for the hospital case in this research. It is assumed that this is paid when the individual is discharged from the hospital.

The third dataset describes membership information including: the sex and date of birth of the individual and the benefit option that they chose over the period of the hospital case (Actuarial Society of South Africa, 2017d).

Additional information is added to these three datasets because the diagnosis and procedure codes are summarised with a DRG.

A linked dataset is created by combining the three datasets and the DRG information. There are 1 818 914 rows where each row represents a hospital case. There are 912 370 individuals that have submitted claims for these hospital cases. A description of the variables in the linked dataset is in section 4.2.

4.2 Description of the variables in the linked dataset

There are a number of variables available in the linked dataset including:

- Sex of the individual;
- Date of birth of the individual;
- Benefit option that the individual chose over the period of the hospital case;
- Pre-authorisation number of the hospital case;
- Practice number of the hospital;
- Start-date and end-date of the hospital case;
- Diagnosis and procedure codes linked to the hospital case;
- MDC of the hospital case;
- Base DRG of the hospital case;
- DRG of the hospital case; and
- Benefit paid for the hospital case.

Some variables are used in the form provided and some are manipulated to meet the objectives of this research. The manipulation of variables is described in this section.

The sex, date of birth of the individual and the benefit option that the individual chose over the period of the hospital case are provided by the administrator (Actuarial Society of South Africa, 2017d).

The pre-authorisation number is issued by the managed care organisation to give individuals authorisation for the hospital case (Actuarial Society of South Africa, 2017a). This is used in this research to identify hospital cases.

The practice number of the hospital and the start-date and end-date of the hospital case are also provided by the managed care organisation, given their role (Actuarial Society of South Africa, 2017d,a). A practice number is issued to each hospital by the Board of HealthCare Funders of Southern Africa and is used for billing and reimbursement purposes and can be used to identify the name of the hospital (Health Market Inquiry, 2017). The start-date describes the admission date of the hospital case. The end-date describes the discharge date of the hospital case.

The date of birth of the individual, with the start-date of the hospital case, is used to calculate the age of the individual at the start-date of the hospital case. Ages are grouped into ten age-bands to ensure that the statistical model is parsimonious (Dobson and Barnett, 2008). Individuals that are aged less than one year are grouped into one age-band. This is in line with standard practice in the medical scheme industry in South Africa. Individuals aged one to ten are grouped into one age-band and ten-year age-bands are used for all other ages. Individuals aged 80 and older are grouped together.

The start-date and end-date of the hospital case is used to calculate the number of bed-days of the hospital case. In this research, a bed-day is considered as the number of nights that an individual stays overnight in a hospital. This is in line with the data from the Healthcare Utilization Project State Inpatient Databases which is used as the reference population by AHRQ (Agency for Healthcare Research and Quality, 2017; Healthcare Cost and

Utilization Project, 2009). It is calculated as the difference between the end-date of the hospital case and the start-date of the hospital case (Agency for Healthcare Research and Quality, 2017; Healthcare Cost and Utilization Project, 2009). For example, an individual is considered as having three bed-days if the hospital case starts on the 1st day of the month and ends on the 4th day of the same month. A bed-day of zero implies that the hospital case starts and ends on the same day.

The diagnosis and procedure codes are provided by the managed care organisation (Actuarial Society of South Africa, 2017d,a). The diagnosis codes are the International Classification of Diseases (ICD) codes developed by the World Health Organisation (Actuarial Society of South Africa, 2017d; South African Department of Health, 2014). These are used to identify the reason for the treatment (Actuarial Society of South Africa, 2017d). There is a primary diagnosis and a number of secondary diagnoses (South African Department of Health, 2014). The procedure codes are developed by the American Medical Association and are used in South Africa in the private sector for data collection and analytic purposes (Actuarial Society of South Africa, 2017d). There are a number of procedure codes used to identify the treatments that are provided (Actuarial Society of South Africa, 2017d). The individual receiving healthcare services at the hospital and the individual providing healthcare services at the hospital provide information relating to the diagnoses and procedures of the hospital case to the managed care organisation¹. In this research, diagnosis and procedure codes are used by the DRG to classify each hospital case. Procedure codes are not used for further analysis in this research. There are 10 diagnosis codes for each hospital case. These are used to identify the diagnosis of a pressure ulcer, as explained in section 5.2.3.

The DRG used in this research is developed by Insight Actuaries and Consultants. The DRG assigns each hospital case to a major diagnostic category (MDC), a base DRG and a DRG (Insight Actuaries and Consultants,

¹L Whitelaw 2018, personal communication, 28 August.

2016). The MDC is a broad clinical classification that corresponds to a body system (Duncan, 2011; Insight Actuaries and Consultants, 2016). For example, MDC 9 describes diseases and disorders of the skin, subcutaneous tissue and breast. The DRG used in this research has 24 MDCs (Insight Actuaries and Consultants, 2016). The description of these is included in Appendix A. A base DRG is a more granular classification and uses diagnosis and procedure codes to assign each hospital case to a base DRG (Insight Actuaries and Consultants, 2016). A DRG is the most granular classification and subdivides base DRGs into DRGs based on the presence of co-morbidities and complications (Insight Actuaries and Consultants, 2016; Duncan, 2011). This sub-division is determined according to the diagnosis codes of the hospital case. All levels of the DRG are mutually exclusive and therefore a hospital case can only be classified according to one description (Duncan, 2011).

The benefit paid for the hospital case is described in section 4.1. This includes all claims submitted by the individual over the period of the hospital case and that are paid by the medical scheme. This therefore includes fees charged by the hospital and specialists that provide services at the hospital. It also includes fees for pharmaceuticals, surgicals and healthcare consumables. The amount that the individual claimed for each medical good or service is not used in this research because this is not considered as a financial implication for the medical scheme.

4.3 Process followed to clean the linked dataset

A thorough process is followed to ensure that the data in the linked dataset are accurate. Hospital cases where the benefit paid is negative or zero and hospital cases where the MDC is defined as error are removed from the linked dataset.

Further checks are done on the linked dataset at a scheme level. These include checks to identify errors in the linked dataset and checks to assess the reasonability of the data in the linked dataset. The details of these are

outlined in Table 4.1 and 4.2. These checks are in line with a standard data cleaning process (Iezzoni, 2012). The checks for errors and the number of hospital cases removed from the linked dataset because of a specified error are shown in Table 4.1.

Table 4.1: Checks for errors

	Description of check	Number of hospital cases
Check 1	Missing values	84
Check 2	Non-unique case numbers	0
Check 3	No end-date	0
Check 4	Total claims submitted for the hospital case are less than the benefit paid for the hospital case	0
Check 5	Impossible and improbable ages	8
Check 6	Impossible and improbable bed-days	28

As shown in Table 4.1, there are a total of 120 hospital cases that are removed from the linked dataset because of data errors. These hospital cases account for less than 1% of all hospital cases. The birth-dates of all individuals aged 99 and older are analysed to determine if there are errors in the linked dataset because age is calculated based on the birth date of the individual. Hospital cases where the number of bed-days indicates that the individual is in the hospital for a period longer than six months are investigated to determine if there are errors in the linked dataset. There are 1 816 056 hospital cases in the linked dataset after the data-cleaning process is completed.

Reasonability checks for each scheme, as described in Table 4.2, are done after the 120 cases, as described in Table 4.1, are removed from the linked dataset.

Table 4.2: Checks for reasonability

	Description of check
Check 1	Benefits paid for all hospital cases relative to total in-hospital benefits paid in each calendar year
Check 2	Average benefit paid per hospital case in each calendar year
Check 3	Number of hospital cases for each individual in each calendar year
Check 4	Average number of bed-days per hospital case in each calendar year
Check 5	Average age of the individuals in the linked dataset relative to the average age of all individuals in each calendar year

The benefit paid is considered in the main objective of this research and is therefore assessed for reasonability in Check 1 and Check 2. Check 3 for reasonability validates Check 2 for errors. Check 5 and 6 for errors results in hospital cases being removed and therefore the impact of removing these cases is assessed in Check 4 and Check 5 for reasonability. The details of these reasonability checks is provided in the subsequent paragraphs.

The first reasonability check is a comparison of the benefits paid using two methods to identify hospital claims. The first method uses the benefit paid that is calculated in this research as a measure of the benefit paid for all hospital claims. The second method assumes that the in-hospital indicator, available in the data provided, accurately identifies all claims that occurred in hospital. This indicator is developed by Insight Actuaries and Consultants. This indicator is only available for 92% of the benefits paid that are used in this research because the data from one of the schemes are not summarised using this indicator. These two values are compared and the benefits paid that are used in this research are 11% less than benefits paid

using the in-hospital indicator to identify the relevant claims. The in-hospital indicator is developed by Insight Actuaries and Consultants where this would also contribute to the discrepancy given the different methodology used to define in-hospital cases. Another reason for this discrepancy could be an administrative error if the incorrect individual, date or hospital name is linked to the claim. This could also be as a result of in-hospital claims that are not linked to a pre-authorisation number. This result therefore seems reasonable.

The second reasonability check evaluates the average benefit paid per hospital case for each scheme in each calendar year. The increase is 7.8% when weighted by the number of hospital cases. This is reasonable given that it is higher than CPI where CPI ranged from 4.6% to 6.4% over this period (Statistics South Africa, 2019). The increase in excess of CPI is expected given the effect of inflation, ageing, new technology and the increased utilisation of services over time (Actuarial Society of South Africa, 2017b).

The third reasonability check compares the cumulative distribution of the number of hospital cases for each individual across the schemes. Approximately 99% of individuals have less than three cases per calendar year and approximately 97% of all individuals have less than two cases per calendar year for all schemes. The results are the same for all schemes and therefore seem reasonable.

The fourth check compares the average number of bed-days per hospital case in each calendar year across the schemes. The average number of bed-days per hospital case ranges between two and three. There is a low variation across the schemes and therefore the results seem reasonable.

The fifth check compares the average age of the individuals used in this research relative to the average age of all individuals in the scheme in each calendar year. This is done for all schemes. The individuals used in this research are, on average, older compared to all individuals in the scheme. This seems reasonable because morbidity risk is higher for older individuals and these individuals are therefore more likely to have a hospital case (Actuarial Society of South Africa, 2017b).

There are no hospital cases removed as a result of the reasonability checks. Further spot checks are done. These include: checks to ensure that the correct administrative data are used to describe the individual and checks to ensure that all claims paid over the period of the hospital case are included.

Chapter 5

Methodology

5.1 Introduction

Statistical modelling is used in this research in the methodology to apply risk adjustment. Four adjustments are applied to the linked dataset so that the linked dataset can be used in the statistical modelling process. These are described in section 5.2. This section includes a description of the linked dataset after the four adjustments are applied. The statistical modelling process is described in section 5.3. The results from the statistical modelling are used in the application of risk adjustment. The details of this process and the statistical tests that are used are described in section 5.4.

5.2 Adjustments applied to the linked dataset

5.2.1 Price adjustment to the distribution of the benefit paid

The objective of risk adjustment in this research is to identify the factors that cause the variation in the benefit paid for each hospital case. The average benefit paid for each hospital case increases across the calendar years, as

described in section 4.3. An adjustment to the linked dataset is therefore made to account for this.

The change in the benefit paid across the calendar years can be analysed by changes in the average benefit paid for each hospital case and changes in the number of hospital cases (Duncan, 2011). The change in the average benefit paid is relevant because comparisons are done based on the average benefit paid for each hospital case. The factors driving the change in the average benefit paid include: inflation, ageing, new technology and the increased utilisation of services (Actuarial Society of South Africa, 2017b).

The medical component of the Consumer Price Index (CPI) is published by Statistics South Africa (Actuarial Society of South Africa, 2017d). The items that are used to measure medical CPI include: contributions paid for medical aid, out-of-pocket healthcare expenditure and the amount paid to traditional healers (Actuarial Society of South Africa, 2017d). Medical CPI is therefore not appropriate to use in this research because it does not measure the factors that drive the change in the average benefit paid because it includes changes in the contributions for medical aid. An index based on the data is therefore more appropriate because it measures the actual changes in the average benefit paid for these hospital cases. The change in the average benefit paid includes changes in the fees charged by hospitals, specialists and the fees charged for pharmaceuticals, surgicals and healthcare consumables. These fees increase at different rates and therefore an index that accounts for all of these increases is appropriate (Ramjee, 2010).

The Lowe price index is used (Ramjee, 2010). The Lowe price index isolates the impact of changes in the average benefit paid and changes in the number of hospital cases. The change in the average benefit paid is expressed relative to a reference period and the number of hospital cases is held constant (Ramjee, 2010). The reference period is 2014 in this research. The benefit paid for all hospital cases is therefore expressed in 2014 terms. The price index includes all hospital cases and is calculated separately for each scheme. The price index is therefore relevant for each scheme. The price index is

calculated as follows:

$$P_{Lowe}^t = \frac{\sum_{i=1}^N P_i^t Q_i^b}{\sum_{i=1}^N P_i^b Q_i^b}$$

where

i represents the i th base DRG;

t is the calendar year for which the price index is calculated;

b is the reference period;

P_i^t represents the average cost of the i th base DRG over the calendar year represented by t ; and

Q_i^b represents the number of hospital cases in the i th base DRG over the reference period.

The change in the average benefit paid is calculated at a base DRG level to ensure that the results are relevant because a base DRG describes the hospital case in more detail compared to the MDC (Insight Actuaries and Consultants, 2016). The change in the average benefit paid is applied at an MDC level to ensure that there are a sufficient number of hospital cases for the index to be credible because the MDC describes a hospital case in less detail compared to the base DRG (The Actuarial Education Company, 2017b; Insight Actuaries and Consultants, 2016). The price index is therefore applied to each hospital case at an MDC level. The assumption is therefore made that the mix of fees at a base DRG level remains constant in each year and the index is therefore limited.

For example, the benefit paid for a hospital case with an end-date in 2017 and classified in the MDC described as “Diseases and disorders of the skin, subcutaneous tissue and breast” is adjusted as follows:

$$R \times \frac{P_{Lowe}^{2014}}{P_{Lowe}^{2017}}$$

where

R represents the benefit paid for this hospital case in 2017.

The Lowe index used in this example is specific to the MDC described as “Diseases and disorders of the skin, subcutaneous tissue and breast”.

There are ten hospital cases removed once the Lowe index is applied because there is no relevant index available to adjust these hospital cases.

The AHRQ-exclusion indicator can also be used to explain the variation in the benefit paid for a hospital case.

5.2.2 Identification of AHRQ-exclusion hospital cases

AHRQ recognises that there are individuals that are more likely to develop pressure ulcers because they have limited mobility, as described in section 3.4 (Agency for Healthcare Research and Quality, 2006). These individuals therefore have a relatively worse risk profile compared to other individuals.

The ICD codes that are used to identify the AHRQ-exclusion hospital cases are available for this research (Agency for Healthcare Research and Quality, 2006; Quan *et al.*, 2008). These codes were provided via email by Dr Hude Quan. These diagnosis codes are summarised with an indicator to define the AHRQ-exclusion hospital cases. These individuals are expected to have a larger benefit paid for their hospital case given their relatively worse risk profile and this indicator is therefore used in the statistical modelling for risk adjustment. This variable is analysed in section 5.3.3.6 to determine if this can explain the variation in the benefit paid.

The results presented in this research provide a comparison between the average benefit paid for a hospital case where an individual is diagnosed with a pressure ulcer and the average benefit paid for a hospital case where an individual is not diagnosed with a pressure ulcer. Hospital cases where an individual is diagnosed with a pressure ulcer are therefore identified.

5.2.3 Identification of hospital cases with pressure ulcers

There are many methods that are used to identify adverse events, including pressure ulcers. These include: applying the AHRQ PSI methodology to administrative data, assessing voluntary reports of adverse events, reviewing

the medical records and charts from the hospital case of the individual or using medical records with the Global Trigger Tool developed by the Institute for Healthcare Improvement (IHI) (Classen, Resar, Griffin, Federico, Frankel, Kimmel, Whittington, Frankel, Seger and James, 2011). The gold standard to identify adverse events is a retrospective review of medical records and charts from the hospital case of the individual (Slawomirski *et al.*, 2017).

Administrative data are used in this research and therefore the AHRQ's PSI methodology is relevant and is used (Classen *et al.*, 2011). Data from hospitals are not available for this research and therefore voluntary reports, medical records and charts are not available. The IHI Global Trigger Tool also requires feedback from a team of at least three individuals (Griffin and Resar, 2009). This method is therefore not suitable for this research.

The methodology published by AHRQ includes details of the codes used to identify adverse events in administrative data (Agency for Healthcare Research and Quality, 2018b). These, however, use the diagnosis and procedure codes used in the United States of America (Quan *et al.*, 2008). The South African diagnosis and procedure codes are available in the linked dataset used in this research. The latest version of this PSI was released in 2018 but a mapping between these two sets of diagnosis codes was done for the 2006 version of the definitions used for 15 PSIs (Quan *et al.*, 2008; Agency for Healthcare Research and Quality, 2018a). This mapping includes the details of the diagnosis codes used in South Africa to identify hospital cases where an individual is diagnosed with a pressure ulcer.

The AHRQ PSI for pressure ulcers is a rate measure of the pressure ulcer rate per 1 000 hospital cases and therefore includes a description of hospital cases included in both the numerator and the denominator.

The details of the hospital cases included in the numerator and denominator of this PSI, using the 2006 version of the definitions, are described in this section. This is used to identify hospital cases where an individual is diagnosed with a pressure ulcer and the hospital cases included in the statistical modelling process.

The hospital cases included in the numerator of this PSI include discharges with ICD-9-CM code of decubitus ulcer in any secondary diagnosis field.

The AHRQ PSI uses the secondary diagnosis field because the aim of the PSI is to identify hospital cases where the pressure ulcer developed at hospital (Agency for Healthcare Research and Quality, 2006).

In South African administrative data, the position of the diagnosis codes do not indicate if the pressure ulcer was present on admission to the hospital or developed at the hospital¹ (South African Department of Health, 2014). These diagnosis codes are the ICD codes described in section 4.2. The primary diagnosis indicates the “main condition treated” for the hospital case (South African Department of Health, 2014). The secondary diagnosis describes “additional conditions that affect patient care or may co-exist with the main condition” and require healthcare resources (South African Department of Health, 2014).

A pressure ulcer that develops at hospital could be classified as the primary diagnosis if this diagnosis uses more resources compared to the other diagnoses². Furthermore, there is no indicator for a pressure ulcer that is present when the individual is admitted to hospital¹. Both the primary and secondary diagnosis codes are therefore used in this research to identify hospital cases where an individual is diagnosed with a pressure ulcer.

The diagnosis code for a pressure ulcer begins with the alpha-numeric code “L89” (Agency for Healthcare Research and Quality, 2006; Quan *et al.*, 2008). Diagnosis codes linked to the first dataset are used because the managed care organisation pre-authorises hospital cases and these diagnosis codes should be accurate (Actuarial Society of South Africa, 2017a).

The denominator inclusions and exclusions for this PSI are also considered to determine the hospital cases included in the statistical modelling process. The denominator inclusions are all medical and surgical discharges for individuals 18 years and older defined by specific DRGs. The denominator exclusions are

¹S Satiyadev 2018, personal communication, 4 September and L Whitelaw 2018, personal communication, 28 August.

²L Whitelaw 2018, personal communication, 28 August.

described in Table 5.1.

All hospital cases are therefore included because both medical and surgical hospital cases are included (Duncan, 2011). The DRGs that are not included in the AHRQ PSI denominator are described in Table 5.1. This table also includes additional denominator exclusions.

Table 5.1: Denominator exclusions for the 2006 AHRQ PSI

	Criteria
1	Cases with length of stay less than 5 days
2	Cases with ICD-9-CM code of decubitus ulcer in the principal diagnosis field
3	Cases with MDC 9 (Skin, subcutaneous tissue, and breast)
4	Cases with an ICD-9-CM diagnosis code of spina bifida or anoxic brain damage
5	Cases with MDC 14 (Pregnancy, childbirth, and puerperium)
6	Cases with any diagnosis of hemiplegia, paraplegia, or quadriplegia
7	Cases with an ICD-9-CM procedure code for debridement or pedicle graft before or on the same day as the major operating room procedure (surgical cases only)
8	Cases admitted from a long-term care facility
9	Cases transferred from an acute care facility

The denominator exclusions reflected in the 2018 version are also considered to ensure that this research reflects the latest version of these definitions. The 2018 version excludes hospital cases where the number of bed-days is less than three days (Agency for Healthcare Research and Quality, 2018a). This condition is used instead of the condition of five days specified in the 2006 version of the indicator (Agency for Healthcare Research and Quality, 2006). Hospital cases where the number of bed-days is less than three are not included in this research. There are 983 813 hospital cases removed because

these cases have less than three bed-days.

Hospital cases where the MDC reflects diseases of the skin, subcutaneous tissue and breast are not excluded in the 2018 version and have not been excluded in this research (Agency for Healthcare Research and Quality, 2018a).

Hospital cases relating to pregnancy, childbirth and the puerperium are excluded in the 2018 version (Agency for Healthcare Research and Quality, 2018a). Hospital cases where the diagnosis code indicates spina bifida, anoxic brain damage, hemiplegia, paraplegia, or quadriplegia are identified as the AHRQ-exclusion hospital cases. Both of these types of cases are not excluded in this research because this research does not aim to assess the relative performance of hospitals.

The ICD-9-CM procedure codes are not available in the linked dataset. The mapping to the South African procedure coding system is also not available. The previous hospital setting of the individuals is not available in this linked dataset. Criteria 7, 8 and 9 are therefore not considered.

Additional changes in the 2018 version are considered. The 2018 version excludes hospital cases where there are missing data for the sex, age, date of the hospital case and primary diagnosis code (Agency for Healthcare Research and Quality, 2018a). This is done in this research when the data are cleaned.

The age of the individual is not considered in this research to ensure that there are a sufficient number of hospital cases included (The Actuarial Education Company, 2017b).

The numerator inclusion for the AHRQ PSI is used to create an indicator variable to identify hospital cases where an individual is diagnosed with a pressure ulcer.

An adjustment is also made to the distribution of the benefit paid to prepare the linked dataset for the statistical modelling for risk adjustment.

5.2.4 Exclusion of outlier hospital cases

Generalised linear models (GLMs) are used in the statistical modelling to identify a statistical distribution that best fits the distribution of the benefit

paid. Iteratively re-weighted least squares is used when fitting a GLM to the distribution of the benefit paid to calculate the maximum likelihood estimate of the parameters (Dobson and Barnett, 2008). Outliers in the benefit paid can affect these estimates (Iezzoni, 2012). Outliers include both extreme low values and extreme high values. These are therefore excluded.

Trimming, top-coding, winsorizing or a logarithmic transformation of the distribution of the benefit paid can be used to account for outliers (Iezzoni, 2012). Trimming removes extreme values of the benefit paid from the linked dataset (Iezzoni, 2012). Top-coding replaces extreme high values by the minimum of the set of values (Iezzoni, 2012). Winsorizing is similar to top-coding but replaces an equal number of both extreme high values and extreme low values (Iezzoni, 2012). Top-coding and winsorizing reduce the influence of outliers by drawing them closer to the mean (Iezzoni, 2012). A logarithmic transformation can be used for outliers because it is assumed that the transformed distribution follows a Gaussian distribution (Iezzoni, 2012). The logarithmic transformation is applied to the entire distribution to improve the fit of the Gaussian distribution (Iezzoni, 2012).

In this research, trimming and top-coding is done to the distribution of the benefit paid. A logarithmic transformation of the distribution of the benefit paid is also done in the statistical modelling process, as described in section 5.3.2.2.

The number of hospital cases considered at both the extreme low and extreme high values of the distribution is the same. The lower 0.5th percentile and upper 99.5th percentile of the distribution of the benefit paid is considered. This includes 9 234 hospital cases in total. This percentile of the distribution ensures that there are a sufficient number of hospital cases included in the analysis so that the results are credible (The Actuarial Education Company, 2017b).

The hospital cases at the lower 0.5th percentile of the distribution have a benefit paid that is less than or equal to R6 660. The average benefit paid per hospital case for all medical schemes in South Africa, not considering

the number of bed-days, is R20 986 (Council for Medical Schemes, 2016). These hospital cases have at least 3 bed-days and it is therefore reasonable to exclude these hospital cases given the comparison with the average benefit paid for all medical schemes.

The hospital cases at the upper 99.5th percentile of the distribution have a benefit paid that is greater than or equal to R664 814. These hospital cases are not trimmed because high-cost hospital cases are characteristic of healthcare data (Shapiro, Childs and Getz, 2013). All of the hospital cases with a benefit paid that is greater than or equal to R664 814 are top-coded where the benefit paid for these hospital cases is replaced by this value. A higher value of the distribution could affect the maximum likelihood estimates of the parameters and is therefore not used (Iezzoni, 2012).

The linked dataset, after the adjustments are made, is used in the statistical modelling and the application of risk adjustment. There are 828 071 hospital cases after these adjustments are made. A description of this linked dataset is provided in section 5.2.5. This describes the linked dataset after the adjustments described in section 5.2.1 to 5.2.4 are applied to the linked dataset.

5.2.5 Description of the linked dataset after the adjustments are applied to the linked dataset

The distribution of the benefit paid in the linked dataset is shown in Figure 5.1.

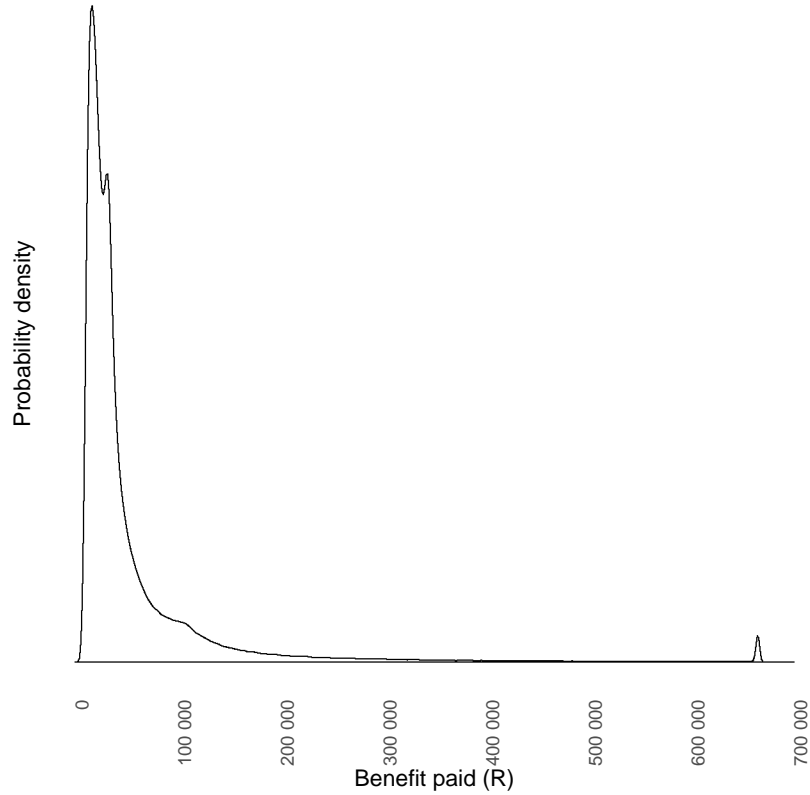


Figure 5.1: Distribution of the benefit paid for all hospital cases

Figure 5.1 shows that the average benefit paid is R53 657 and the standard deviation is R78 763. The maximum benefit paid is R664 814, given the adjustments to the linked dataset. The co-efficient of skewness is 4.71 indicating that the distribution of the benefit paid is positively skewed (Rice, 1995).

There are 4 738 hospital cases that are classified as AHRQ-exclusion hospital cases. These represent approximately 0.57% of all hospital cases.

There are 3 700 hospital cases where the individual is diagnosed with a pressure ulcer. These represent approximately 0.45% of all hospital cases. The distribution of these hospital cases based on the position of the pressure

ulcer diagnosis code is shown in Table 5.2.

Table 5.2: Distribution of hospital cases where an individual is diagnosed with a pressure ulcer

	Primary diagnosis	Secondary diagnosis	Primary and secondary diagnosis
Number of cases	107	3 145	448
Number of cases per 1 000 hospital cases	0.13	3.80	0.54

Table 5.2 shows that the number of hospital cases where the pressure ulcer diagnosis code indicates only a primary diagnosis is low relative to the secondary diagnosis. Identifying the hospital cases where the individual develops a pressure ulcer at the hospital, however, is inaccurate. It is not possible to identify pressure ulcers that developed in hospital based only on the available diagnosis codes given the nature of the administrative data in South Africa³. Including all hospital cases in Table 5.2 is therefore an over-estimate of the number of pressure ulcers that developed at hospital and are considered as adverse events (Slawomirski *et al.*, 2017). A detailed review of the clinical records would need to be done to identify hospital cases where the pressure ulcer developed at hospital⁴.

Females account for approximately 67% of all hospital cases in the linked dataset. The number of individuals in each age-band is shown in Figure 5.2.

³S Satiyadev 2018, personal communication, 4 September and L Whitelaw 2018, personal communication, 28 August.

⁴L Whitelaw 2018, personal communication, 28 August.

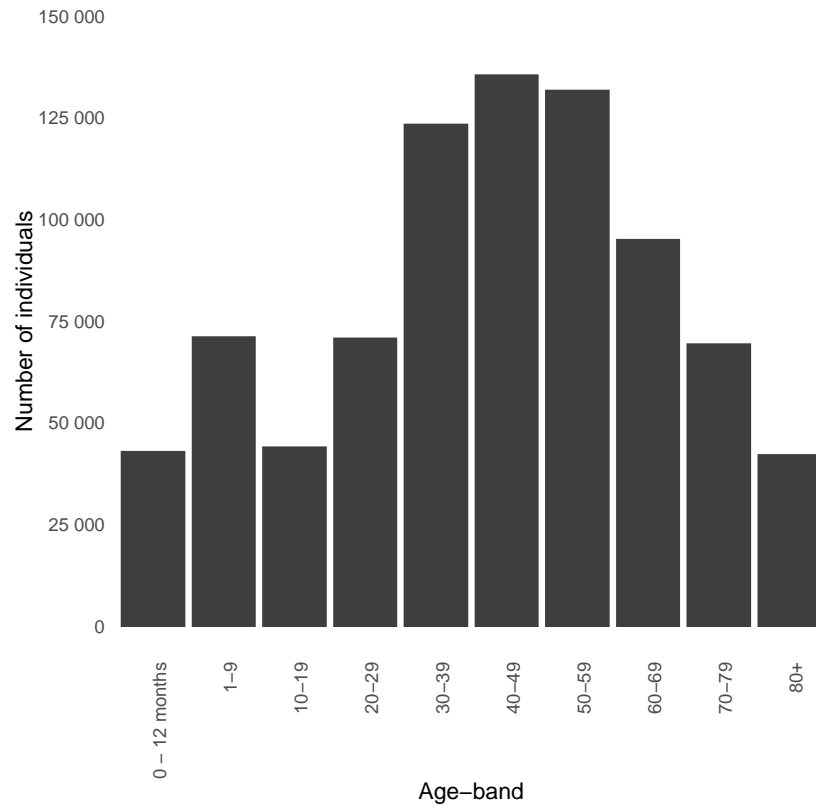


Figure 5.2: Distribution of the number of hospital cases by age-band

Figure 5.2 highlights the older age profile of the individuals in the linked dataset. There are 391 333 individuals between the ages of 30 and 59. These individuals account for approximately 47% of all hospital cases. The number of hospital cases in each MDC is shown in Figure 5.3.

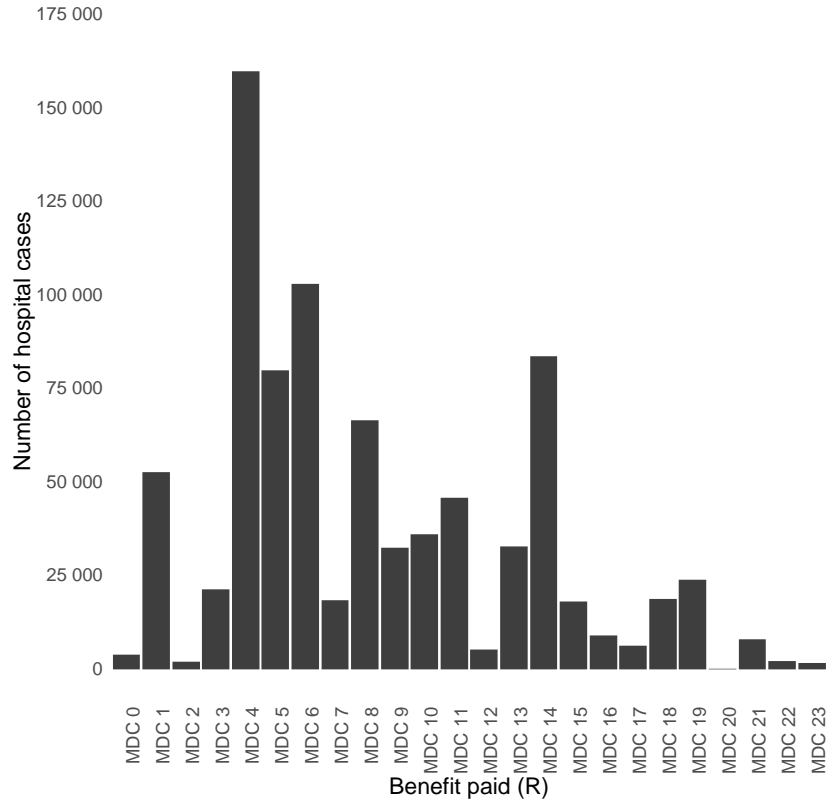


Figure 5.3: Distribution of the number of hospital cases by MDC

Figure 5.3 shows that MDC 4, which includes cases where the individual has diseases and disorders of the respiratory system, accounts for approximately 19% of all hospital cases. Hospital cases in MDC 6, where the individual has diseases and disorders of the digestive system, account for approximately 12% of all hospital cases. A description of all of the MDCs is included in Appendix A.

5.3 Description of the statistical modelling for risk adjustment

5.3.1 Description of the risk adjustment method used

Statistical modelling is used to identify the factors that explain the variation in the benefit paid for a hospital case (Dobson and Barnett, 2008). These factors are used to group hospital cases into risk cells. The distribution of the benefit paid within a risk cell is statistically homogeneous (Insight Actuaries and Consultants, 2016). This is therefore used to risk-adjust the results. The source of variation in the benefit paid between a hospital case where an individual is diagnosed with a pressure ulcer compared to a hospital case where an individual is not diagnosed with a pressure ulcer, within a risk cell, is therefore driven by the diagnosis of the pressure ulcer.

Statistical modelling is used as the method of risk adjustment because there are 828 071 hospital cases and there are therefore a sufficient number of hospital cases available to build a statistical model (Rubin *et al.*, 2001). Iezzoni recommends that "thousands of cases" are needed for non-normally distributed outcome variables (Iezzoni, 2012:pg.254). Statistical modelling using this linked dataset identifies the factors that are relevant to these individuals. This is a better methodology compared to using only a clinical grouper. A clinical grouper would not include additional factors that are likely to be relevant to the individuals in this linked dataset (The Actuarial Education Company, 2017b). Statistical tests, as described in section 5.4, are also used given the limited results of the statistical models.

An alternative method, based on propensity scores, could have been used (Iezzoni, 2012). The response variable of the logistic regression model would have been the diagnosis of a pressure ulcer and the model would have been used to predict the probability that the individual developed a pressure ulcer during their hospital case (Iezzoni, 2012). This predicted probability value would have been used as the propensity score for the hospital case (Iezzoni,

2012). Individuals would have been grouped into risk cells based on the value of their propensity score (Iezzoni, 2012). A comparison between the average benefit paid for a hospital case where the individual is diagnosed with a pressure ulcer compared to a hospital case where the individual is not diagnosed with a pressure ulcer would have been done between individuals with similar propensity scores (Iezzoni, 2012).

This research does not have an intervention and this method is therefore not relevant. Hospital cases where an individual is diagnosed with a pressure ulcer are 0.45% of all hospital cases. The results of this statistical model would have been less credible compared to building a statistical model with all hospital cases (The Actuarial Education Company, 2017b).

The linked dataset is split into two linked datasets for the statistical modelling. The training linked dataset is used in the statistical modelling to determine the parameter estimates of the GLMs, as described in section 5.3.2 to 5.3.4 (Duncan, 2011). The training linked dataset has 414 036 hospital cases. The test linked dataset is used to validate the results of the statistical models, as described in section 5.3.4 (Duncan, 2011). The test linked dataset has 414 035 hospital cases.

5.3.2 Process followed to assess the fit of the statistical distributions to the distribution of the benefit paid

5.3.2.1 Analysis of the distribution of the benefit paid

The nature of the response variable and the design of the research determine the statistical model that is used (Dobson and Barnett, 2008). The response variable in this research is the benefit paid for the hospital case. The response variable is continuous and this research aims to determine the relationship between the explanatory variables chosen and the benefit paid for a hospital case to identify the factors that affect the benefit paid for a hospital case (Duncan, 2011). A GLM is appropriate to the design of the research and

therefore the nature of the response variable determines the choice of the statistical model. A statistical distribution from the family of GLMs is used given the positively skewed nature of the distribution, as described in section 5.2.5 (Dobson and Barnett, 2008; Department of Statistical Sciences, 2015).

The Gamma and the inverse Gaussian distribution are therefore used (Department of Statistical Sciences, 2015). The Weibull and exponential distribution could have been tested (Damodaran, 2007; Department of Statistical Sciences, 2015). The Weibull and the exponential distribution are usually used to model survival times and therefore do not correspond to the nature of the response variable (Dobson and Barnett, 2008).

5.3.2.2 Measurement of the fit of the statistical distributions to the distribution of the benefit paid

Three statistical measures are used to assess the fit of these GLMs to the distribution of the benefit paid. The Kolmogorov-Smirnov test is non-parametric and it is used to test if the location, dispersion and shape of the distribution of the benefit paid is the same as that of the statistical distribution (Teetor, 2011). A quantile-quantile (QQ) plot compares the empirical quantiles of the distribution of the benefit paid with the quantiles of the statistical distribution (Department of Statistical Sciences, 2015). A plot of the distribution of the benefit paid with the statistical distribution superimposed is done to assess the fit graphically (Department of Statistical Sciences, 2015). The parameters of the Gamma distribution and the inverse Gaussian distribution are estimated using the method of moments for this plot (Giner and Smyth, 2016; Department of Statistical Sciences, 2015).

The Gaussian distribution is initially fitted to the untransformed distribution of the benefit paid. All three measures indicate that this distribution does not fit the distribution of the benefit paid. A logarithmic transformation of the distribution of the benefit paid is done to account for the skewness of this distribution (Basu, Manning and Mullahy, 2004; Iezzoni, 2012). There is an improvement in the results when this is done and therefore the Gaussian

distribution is fitted to the transformed distribution of the benefit paid.

The results of the tests used to assess the fit of the three statistical distributions to the distribution of the benefit paid are shown in Table 5.3.

Table 5.3: Results from fitting statistical distributions to the distribution of the benefit paid

	Gamma distribution	Inverse Gaussian distribution	Gaussian distribution
Kolmogorov-Smirnov test	Does not fit the response	Does not fit the response	Does not fit the response
QQ plot	Could fit the response	Could fit the response	Could fit the response
Plot of empirical and fitted distribution	Could fit the response	Could fit the response	Could fit the response

The results for the Gaussian distribution are based on the logarithmic transformation of the distribution of the benefit paid. The results in Table 5.3 indicate that all three statistical distributions could be fitted to the distribution of the benefit paid. The QQ plots and plots of the empirical and fitted distribution are shown in Appendix B. All three statistical distributions are therefore used, as described in section 5.3.4.

5.3.3 Analysis of the variables

5.3.3.1 Introduction

There are a number of variables available in the linked dataset, as described in section 4.2. The nature and relevance of these variables is considered when deciding on the variables that are tested for inclusion in the statistical model as explanatory variables. Consideration is also made for the number of levels

of a variable. A variable with many levels is undesirable because a more parsimonious statistical model is preferred (Dobson and Barnett, 2008).

Statistical tests are then used to determine the variables that are included in the model. The association between these variables and the distribution of the benefit paid is examined.

The Mann-Whitney and the Kruskal-Wallis tests are used to measure these associations. The Mann-Whitney test is a non-parametric test and is suitable given that the distribution of the benefit paid does not fit a Gaussian distribution (Hart, 2001). It is used to test for a difference in location, as measured by the median, and assumes, in this research, that the two samples of hospital cases are independent (Hart, 2001). The two-sided test is used because the test is used to assess if the medians of the two samples of hospital cases are equal to each other (Hart, 2001). The Kruskal-Wallis test is used to compare more than two independent samples (Kruskal and Wallis, 1952). It has the same assumptions as the Mann-Whitney test (Hart, 2001). It is also used to test if the distributions of the hospital cases differ with respect to location (Kruskal and Wallis, 1952). A 5% level of significance is used to test these associations (Iezzoni, 2012).

Other distributional differences of the distribution of the benefit paid, using the levels of these variables, are considered and discussed when analysing the results of these statistical tests (Hart, 2001). Box-and-whisker plots are therefore used to show these distributional differences in addition to the results from the statistical tests (Teetor, 2011). These box-and-whisker plots do not show the distribution of the benefit paid after it has been normalised for other variables

5.3.3.2 Selection of variables for inclusion in the statistical model

Sex and age are considered as reliable risk factors to assess the risk of an individual (Duncan, 2011; Actuarial Society of South Africa, 2017c).

The cases included in this research occur in-hospital. Legislation in South Africa requires medical schemes to pay for prescribed minimum benefits in full

where these benefits are usually covered in-hospital (Department of Health, 1998). The benefits paid across all of the options should therefore not differ as a result of the structure of the benefits. The legislation, however, allows medical schemes to restrict these benefits (Health Market Inquiry, 2018). For example, they can specify hospitals that need to be used for the benefits to be paid in full (Health Market Inquiry, 2018). It is, however, difficult to compare benefit options to create a summarised classification of these options (Health Market Inquiry, 2017). Therefore, in the interests of keeping the model parsimonious, the benefit option is not included as an explanatory variable (Dobson and Barnett, 2008).

The pre-authorisation number is used to identify hospital cases and is therefore not considered as an explanatory variable.

It is assumed that the number of bed-days is correlated with the distribution of the benefit paid and it is therefore not included as an explanatory variable.

Hospitals do not need to be identified in this research because this research does not aim to assess the relative performance of hospitals. It is also in the interest of keeping the model parsimonious to not include this as an explanatory variable because there are 246 unique hospitals (Dobson and Barnett, 2008).

The linked dataset includes more than 14 000 unique diagnosis codes and more than 5 000 unique procedure codes. These codes are summarised by the MDC and it is therefore not necessary to include the diagnosis and procedure codes as explanatory variables. This also ensures that the statistical model is parsimonious (Insight Actuaries and Consultants, 2016; Dobson and Barnett, 2008).

The MDC of the hospital case is included to account for the variation in the benefit paid that can be explained by clinical factors (Duncan, 2011). There are 24 MDCs. There are 392 base DRGs and 1 133 DRGs and this information is summarised by the MDC (Insight Actuaries and Consultants, 2016). The base DRGs and DRGs are excluded to ensure that the statistical model is parsimonious (Dobson and Barnett, 2008).

The hospital cases classified as AHRQ-exclusion hospital cases include individuals that are more likely to develop pressure ulcers (Agency for Healthcare Research and Quality, 2006). This is therefore tested for inclusion as an explanatory variable because these individuals are likely to have a larger benefit paid for their hospital case given their relatively worse risk profile.

The four variables that are tested for inclusion in the statistical model as explanatory variables are therefore :

- Sex of the individual;
- Age of the individual;
- MDC of the hospital case; and
- AHRQ-exclusion classification of the hospital case.

These explanatory variables are therefore explored in further detail. The other explanatory variables were not tested for inclusion in the model. The distribution of the benefit paid by sex is shown in Figure 5.4.

5.3.3.3 Statistical analysis of the distribution of the benefit paid by sex of the individual

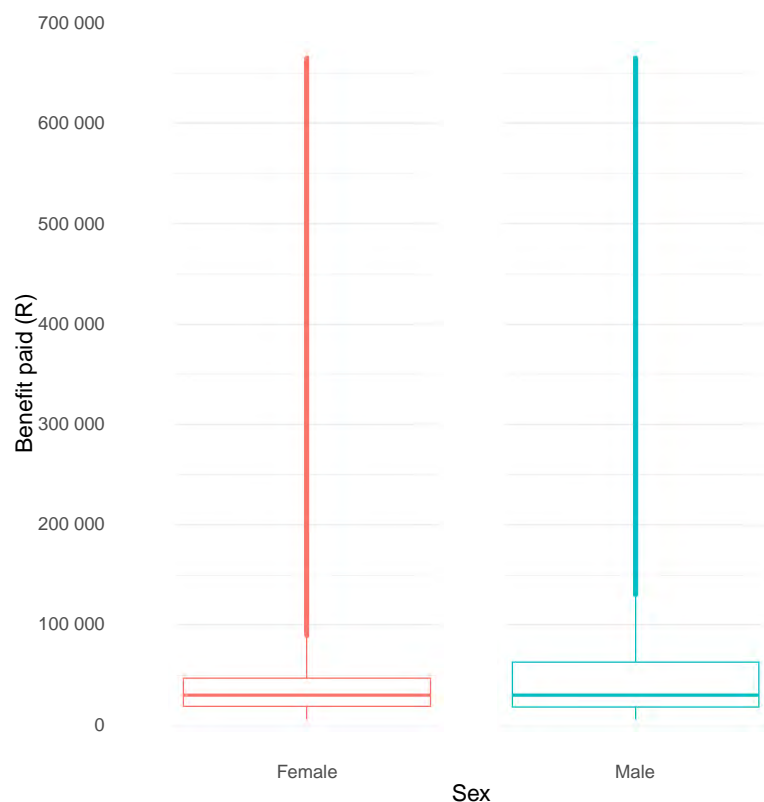


Figure 5.4: Distribution of the benefit paid by sex

The box-and-whisker plot shows the positively skewed nature of the distribution for females and males. The median benefit paid for females is R30 224 and the median benefit paid for males is R30 107. The average benefit paid for females is R49 321 with a standard deviation of R69 923 and the average benefit paid for males is R62 368 with a standard deviation of R93 232.

The Mann-Whitney test indicates that the distribution of the benefit paid for females is statistically different from the distribution of the benefit paid

for males. The distribution of the benefit paid by age-band is shown in Figure 5.5.

5.3.3.4 Statistical analysis of the distribution of the benefit paid by age-band of the individual

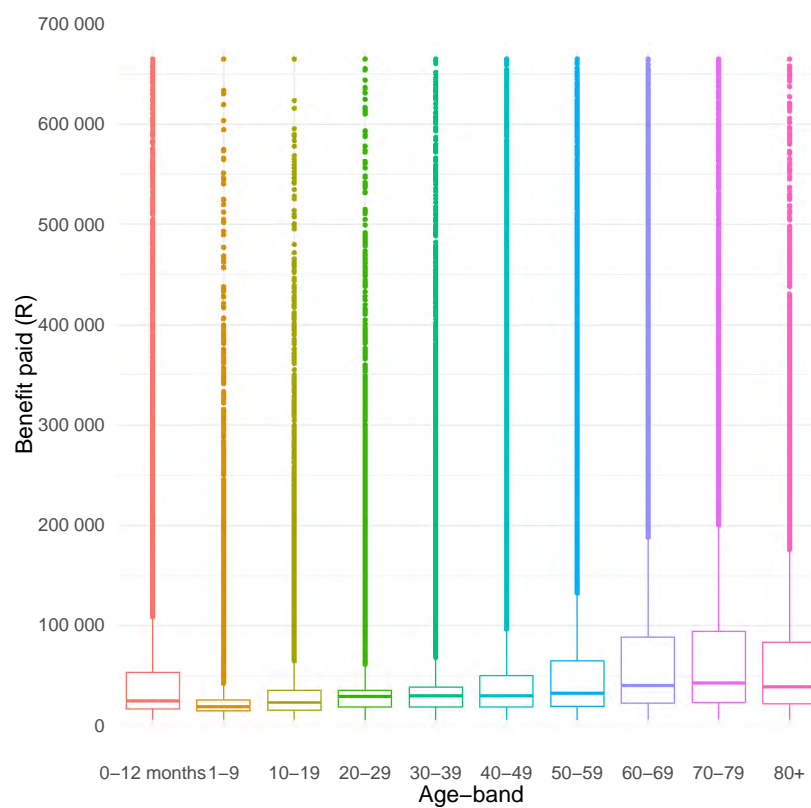


Figure 5.5: Distribution of the benefit paid by age-band

The box-and-whisker plot shows the positively skewed nature of the distribution for all age-bands. The median benefit ranges from R19 351 to R43 213 across the age-bands. The average benefit paid ranges from R26 512 to R78 474

across the age-bands. The standard deviation of the benefit paid ranges from R35 906 to R109 415 across the age-bands.

The Kruskal-Wallis test indicates that the distribution of the benefit paid across the age-bands is statistically different. The distribution of the benefit paid by MDC is shown in Figure 5.6.

5.3.3.5 Statistical analysis of the distribution of the benefit paid by MDC of the hospital case

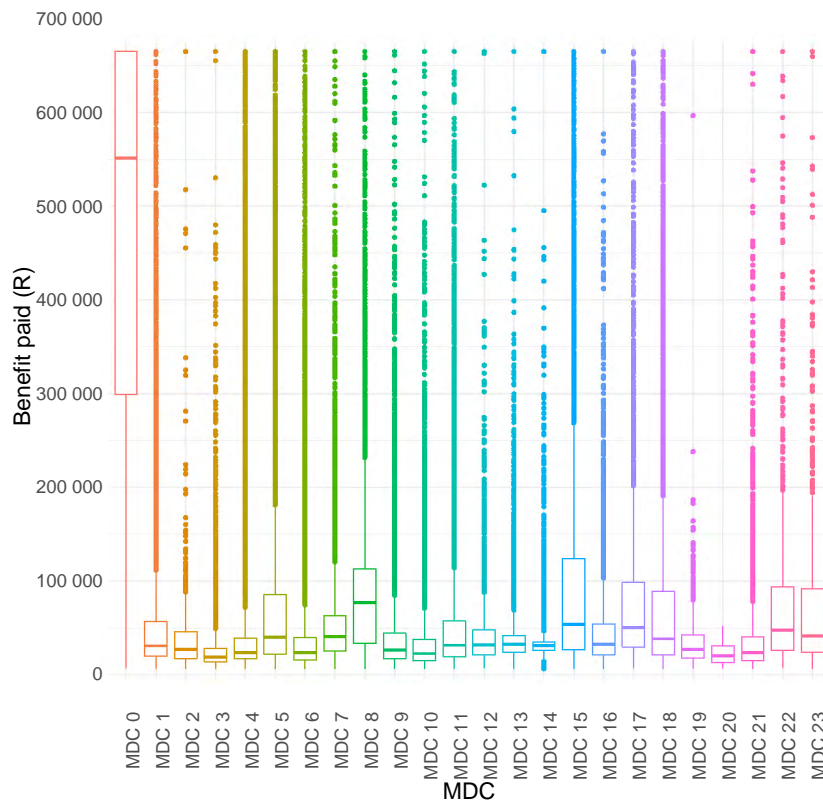


Figure 5.6: Distribution of the benefit paid by MDC

The box-and-whisker plot shows the positively skewed nature of the distribution for all MDCs, except MDC 0. The median benefit ranges from R18 977 to R551 016. The average benefit ranges from R23 073 to R474 913 and the standard deviation ranges from R12 686 to R206 422. MDC 0, which includes hospital cases relating to transplants and critical care, has the largest average benefit paid and the largest standard deviation.

The Kruskal-Wallis test indicates that the distribution of the benefit paid across the MDCs is statistically different. The distribution of the benefit paid by AHRQ-exclusion indicator is shown in Figure 5.7.

5.3.3.6 Statistical analysis of the distribution of the benefit paid by AHRQ-exclusion classification of the hospital case

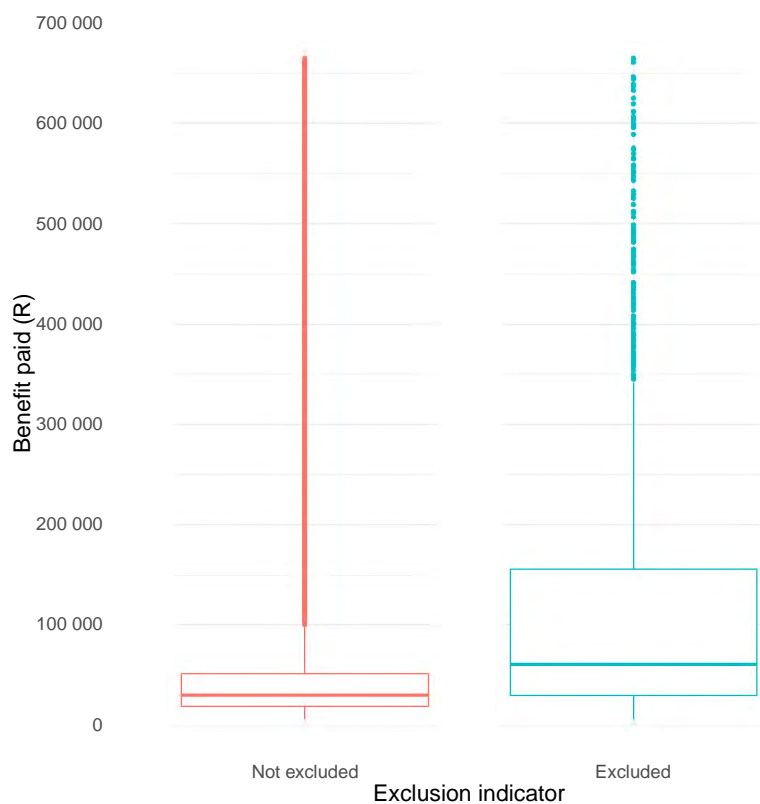


Figure 5.7: Distribution of the benefit paid by AHRQ-exclusion indicator

The box-and-whisker plot shows the positively skewed nature of the distribution for both groups of hospital cases. The median benefit for individuals that would be excluded is R60 816 compared to R30 126 for individuals that would not be excluded. The average benefit paid for individuals that would be excluded is more than two times the average benefit paid for individuals that would not be excluded. The average benefit paid for individuals that would be excluded is R131 024 compared to an average benefit of R53 231

for individuals that would not be excluded. The standard deviation of the benefit paid for individuals that would be excluded is R163 496 compared to R77 741 for individuals that would not be excluded.

The Mann-Whitney test indicates that the distribution of the benefit paid is statistically different for these groups of individuals.

5.3.4 Process followed to build the statistical models

5.3.4.1 Process followed to fit the statistical distributions to the distribution of the benefit paid

All three statistical distributions are fitted to the distribution of the benefit paid because the results, as shown in Table 5.3, indicate that all three distributions perform the same when assessing the goodness of fit to the distribution of the benefit paid. The Gaussian distribution is fitted to the logarithmic transformation of the distribution of the benefit paid.

Four explanatory variables are included in the statistical model given the results of the analyses in section 5.3.3. There are 414 036 hospital cases in the training linked dataset resulting in 103 509 hospital cases per explanatory variable. This is a sufficient number of hospital cases given that the distribution of the benefit paid is skewed (Iezzoni, 2012).

5.3.4.2 Assessing the results of the statistical models

The following results are used to assess the fit of the statistical models:

- The AIC value of the statistical model; and
- The residuals of the statistical model.

The statistical model that has the lowest AIC value and that has residuals that meet the assumptions of the model is used to identify the factors that are used to group hospital cases and create risk cells (Duncan, 2011; Department of Statistical Sciences, 2015). Plots are used to analyse the residuals of the model. The results of the models are summarised in Table 5.4.

Table 5.4: Results of the statistical models

	Model 1	Model 2	Model 3
Distribution	Gamma	Inverse Gaussian	Gaussian
Explanatory variables	Sex, Age-band, MDC, AHRQ exclusion classification	Sex, Age-band, MDC, AHRQ exclusion classification	Sex, Age-band, MDC, AHRQ exclusion classification
Link function	Log	Log	Identity
AIC	9 690 315	9 548 859	926 583
Residual plot 1	Positive residuals for small predicted values and negative residuals for large predicted values.	Positive residuals for small predicted values and negative residuals for large predicted values.	Positive residuals for small predicted values and negative residuals for large predicted values.
Residual plot 2	Standard deviance residuals for small predicted values are smaller than expected.	Standard deviance residuals for small predicted values are smaller than expected.	Standard deviance residuals for small predicted values are smaller than expected.
Residual plot 3	Small predicted values have relatively more variability in the standard deviance residuals.	Small predicted values have relatively more variability in the standard deviance residuals.	Small and large predicted values have relatively more variability in the standard deviance residuals.
Residual plot 4	Some hospital cases have high leverage.	Some hospital cases have high leverage or a large residual.	Some hospital cases have high leverage.
Histogram of residuals	Residuals are centred around zero.	Residuals are centred around zero.	Residuals are centred around zero and have a constant variance.

Model 3 has a lower AIC value compared to model 1 and model 2. All three models have similar results when assessing the four residual plots.

The positive residuals for the small predicted values indicate that the model underestimates the values for the relatively smaller values of the benefit paid. The negative residuals for the large predicted values indicate that the model overestimates the values for the relatively larger values of the benefit paid. This is likely to be as a result of the exclusion of outlier hospital cases.

The residuals for model 1 and model 2 are centred around zero but do not have a constant variance around the centre because the residuals are skewed to the right.

Model 3 has the lowest AIC value and the residuals of the model best meet the assumptions of the model, as seen in the histogram of the residuals. The results from model 3 are used in the application of risk adjustment.

Model 3 is cross-validated to test the predictive accuracy of the model using the test linked dataset (Duncan, 2011; Iezzoni, 2012). Model 1 and 2 are also cross-validated to assess the relative predictive accuracy of the models (Duncan, 2011; Iezzoni, 2012). The parameter estimates of each model are used to calculate a predicted benefit paid for each individual in the test linked dataset (Duncan, 2011). The logarithmic transformation of the response variable is considered in the calculation for model 3. The predicted value is compared to the actual benefit paid and the distribution of the residuals is analysed.

The residuals for model 3 are skewed to the right, as measured by a coefficient of skewness of 4.63, resulting in the largest difference between the actual and the predicted values relative to model 1 and model 2 (Rice, 1995). The proportion of residuals centred around zero for model 3, however, is larger compared to the other two models. Model 3 therefore has a better fit compared to the other two models. The use of model 3 in the methodology to apply risk adjustment is therefore valid.

Residual plots 1-4 are shown in Appendix C.

5.4 Description of the methodology to apply risk adjustment

A process is followed to use the results from model 3 to group the hospital cases into risk cells. There are three steps in this process. Hospital cases from both the training linked dataset and the test linked dataset are included in this process.

The first step in the process classifies all hospital cases into groups. The characteristics of these groups are based on the explanatory variables. The four explanatory variables used in the statistical model result in 960 groups because qualitative explanatory variables are used and there are many levels of each explanatory variable (Dobson and Barnett, 2008). These groups include hospital cases where an individual is diagnosed with a pressure ulcer and hospital cases where an individual is not diagnosed with a pressure ulcer. Only 379 groups have at least one hospital case where an individual is diagnosed with a pressure ulcer. These groups are used in the second step of the process.

The second step uses the results from model 3 because this is the model that performs the best. A baseline group is used as a reference point and describes the characteristics of the baseline individual in model 3. The baseline group is one of the 379 groups. These characteristics are chosen to ensure that there are a sufficient number of hospital cases where an individual is diagnosed with a pressure ulcer in the baseline group. There are 6 521 hospital cases in the baseline group.

The results from model 3 are used to identify other groups where the distribution of the benefit paid is statistically homogeneous compared to the distribution of the benefit paid of the baseline group. The explanatory variables of this model that are not statistically significant, at the 5% level of significance, are identified as the factors used to combine groups with the baseline group.

The results of model 3 show that there are four MDCs where the distribution of the benefit paid is not statistically different relative to the distribution of

the benefit paid for the baseline MDC. The results show that there is one age-band where the distribution of the benefit paid is not statistically different relative to the distribution of the benefit paid for the baseline age-band. These groups and the baseline group are described in Table 5.5.

Table 5.5: Groups where the distribution of the benefit paid is statistically homogeneous relative to the distribution of the benefit paid in the baseline group

	Gender	AHRQ- exclusion	Age- band	MDC	Number of pressure ulcer cases
Baseline	Female	0	80+	Diseases and disorders of the skin, subcutaneous tissue and breast	108
Group 1	Female	0	60-69	Diseases and disorders of the skin, subcutaneous tissue and breast	50
Group 2	Female	0	80+	Diseases and disorders of the eye	0
Group 3	Female	0	80+	Diseases and disorders of the male reproductive system	0
Group 4	Female	0	80+	Mental diseases and disorders	0
Group 5	Female	0	80+	Injuries, poisoning and toxic effects of drugs	2

The results from group 3 do not seem reasonable because these individuals are classified as female but the MDC indicates that their diagnosis relates to the male reproductive system. There are only 11 hospital cases in this group and these hospital cases are therefore excluded from further analysis. This is likely to have been as a result of a data error. Group 1, 2, 4 and 5 are combined with the baseline group to create the baseline group. These groups have different MDCs and combining these groups does not make clinical sense (John Hopkins University, 2011). This is, however, done in this research because the aim is to ensure that the risk cells are statistically homogeneous in terms of the benefit paid and the clinical interpretation of the results is not considered (John Hopkins University, 2011). Resource utilisation bands (RUBs), for example, are used as part of a grouper to classify hospital cases based on resource consumption and do not consider the clinical interpretation of these classifications (John Hopkins University, 2011).

The third step in the process considers all other groups from the first step that are not combined with the baseline group, given the results from the model. Only groups with at least 30 hospital cases where an individual is diagnosed with a pressure ulcer are considered to ensure that the analysis is credible (John Hopkins University, 2011; The Actuarial Education Company, 2017b). Groups that have less than 30 hospital cases where an individual is diagnosed with a pressure ulcer are excluded from further analysis. A statistical test is used to assess if the distribution of the benefit paid of these groups is statistically different to the distribution of the benefit paid of the baseline group. These statistical tests are done because no additional results can be used from the GLM. Statistical tests are done for all pairwise combinations of the baseline group and the other groups. For example, five additional groups would result in 15 statistical tests, as shown in Table 5.6.

Table 5.6: Tests used to group hospital cases

	Group A	Group B
Test 1	Baseline	Group 1
Test 2	Baseline	Group 2
Test 3	Baseline	Group 3
Test 4	Baseline	Group 4
Test 5	Baseline	Group 5
Test 6	Group 1	Group 2
Test 7	Group 1	Group 3
Test 8	Group 1	Group 4
Test 9	Group 1	Group 5
Test 10	Group 2	Group 3
Test 11	Group 2	Group 4
Test 12	Group 2	Group 5
Test 13	Group 3	Group 4
Test 14	Group 3	Group 5
Test 15	Group 4	Group 5

Two measures are used in each test to assess the statistical difference in the distribution of the benefit paid. The Mann-Whitney test is used to test for a difference in the location of the distributions while the Welch two sample t-test is used to test for a difference in the mean of the two distributions (Hart, 2001; Teetor, 2011). The Welch two sample t-test is suitable when either the number of hospital cases included in the test is large or when the distribution of the benefit paid is Gaussian (Teetor, 2011). The distribution of the benefit paid does not follow a Gaussian distribution but there are a sufficient number of hospital cases in each group given the restriction on the number of hospital cases per group.

The groups where the distribution of the benefit paid is not statistically different at the 5% level of significance, according to these two measures, are merged into one risk cell. The number of hospital cases where an

individual is diagnosed with a pressure ulcer is also considered given all possible combinations of the results of these tests (John Hopkins University, 2011; The Actuarial Education Company, 2017b). For example, using Table 5.6, test one and test six could indicate that the baseline should be combined with group one and that group one should be combined with group two. Maximising the number of hospital cases where an individual is diagnosed with a pressure ulcer is therefore considered when deciding on the groups that are combined to form risk cells⁵(John Hopkins University, 2011; The Actuarial Education Company, 2017b).

There are 38 additional groups that have at least 30 hospital cases where an individual is diagnosed with a pressure ulcer. These are the only groups that are considered to ensure that there are a sufficient number of hospital cases where an individual is diagnosed with a pressure ulcer in the final risk cells (John Hopkins University, 2011; The Actuarial Education Company, 2017b). There are 741 tests used for all pairwise combinations of these groups and the baseline group. This results in 1 482 results because there are two measures in each test.

There are 28 tests where both measures indicate that the distribution of the benefit paid for the two groups is not statistically different, when measured at the 5% level of significance. This accounts for 28 of the 38 additional groups. These results and the number of hospital cases per group are considered to determine the groups that are combined into risk cells.

The ten groups where both measures do not indicate that they should be combined with another group are not analysed further.

The results of these tests are used and 25 risk cells are created, including the baseline risk cell. The characteristics of the groups combined to form the baseline risk cell are shown in Table 5.7.

⁵B Childs 2018, personal communication, 12 September.

Table 5.7: Description of the baseline risk cell

Gender	Age-band	MDC
Female	80+	Diseases and disorders of the skin, subcutaneous tissue and breast
Female	60-69	Diseases and disorders of the skin, subcutaneous tissue and breast
Female	80+	Diseases and disorders of the eye
Female	80+	Mental diseases and disorders
Female	80+	Injuries, poisoning and toxic effects of drugs

The results from the statistical model are used to create the baseline risk cell, as shown in Table 5.7. The results from the statistical tests do not indicate that another group should be combined with the baseline group to form the baseline risk cell. The characteristics of the individuals in the other 24 risk cells are described in Appendix D.

There are 173 226 hospital cases included in all risk cells given that only groups with at least 30 hospital cases where an individual is diagnosed with a pressure ulcer are considered. There are a total of 1 870 hospital cases where an individual is diagnosed with a pressure ulcer included in these risk cells. This represents 50.54% of all hospital cases where an individual is diagnosed with a pressure ulcer in the linked dataset. The diagnosis code for 1 802 of these hospital cases indicates that the pressure ulcer is a secondary diagnosis.

The risk cells that are created from this process are used in the final analysis to estimate the financial implications of pressure ulcers.

Chapter 6

Results

6.1 Introduction

The average benefit paid for a hospital case where an individual is diagnosed with a pressure ulcer is compared to the average benefit paid for a hospital case where an individual is not diagnosed with a pressure ulcer for all risk cells. The difference in these two values is considered as the additional cost that can be attributed to the diagnosis of a pressure ulcer. The comparison of the results within a risk cell is on a risk-adjusted basis

The Mann-Whitney test is used to test for a difference in location in the distribution of the benefit paid between the hospital cases where an individual is diagnosed with a pressure ulcer and the hospital cases where an individual is not diagnosed with a pressure ulcer for all risk cells (Hart, 2001). The Welch two sample t-test is also used to test for a difference in the mean of the two distributions (Teetor, 2011).

Figure 6.1 shows the distribution of the average benefit paid for a hospital case where an individual is diagnosed with a pressure ulcer compared to the average benefit paid for a hospital case where an individual is not diagnosed with a pressure ulcer for all risk cells. This figure includes hospital cases where the pressure ulcer diagnosis code indicates either a primary diagnosis, a secondary diagnosis or both diagnoses.

6.2 Estimation of the financial implications of pressure ulcers

6.2.1 Analysis of the average benefit paid including the primary and the secondary diagnosis

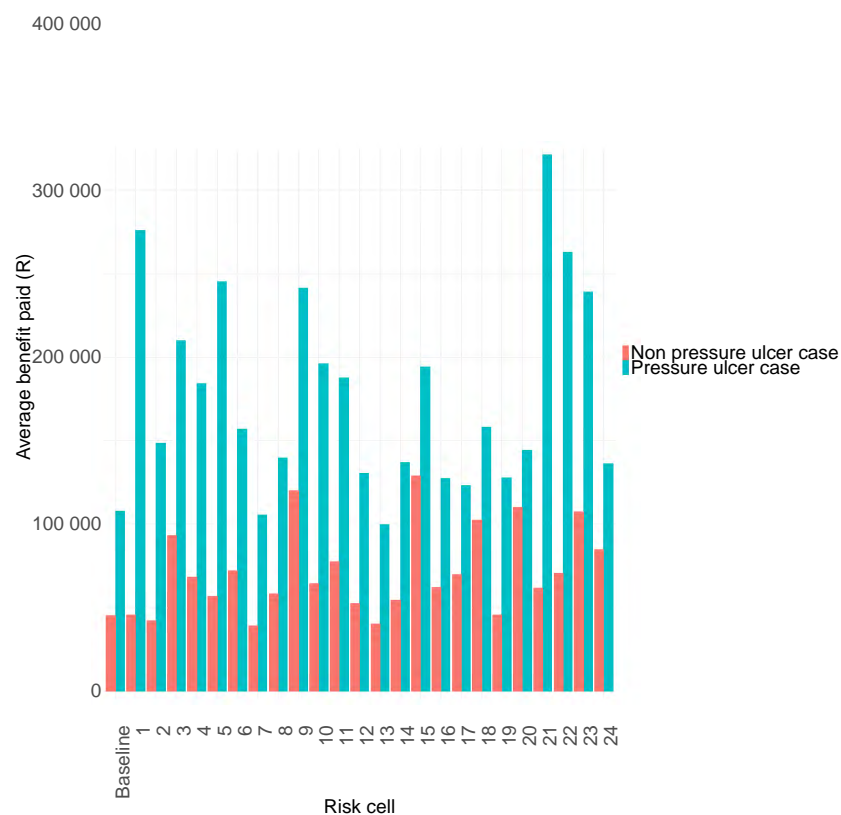


Figure 6.1: Distribution of the average benefit paid by risk cell including the primary and secondary diagnosis

Figure 6.1 shows that risk cell one has the largest variation in the average benefit paid. The average benefit paid for a hospital case where an individual

is diagnosed with a pressure ulcer is 6.04 times the average benefit paid for a hospital case where an individual is not diagnosed with a pressure ulcer. This risk cell includes females and males between the ages of 50 to 59 with diseases and disorders of the skin, subcutaneous tissue and breast.

Figure 6.1 shows that risk cell 20 has the smallest variation in the average benefit paid. The average benefit paid for a hospital case where an individual is diagnosed with a pressure ulcer is 1.32 times the average benefit paid for a hospital case where an individual is not diagnosed with a pressure ulcer. This risk cell includes females and males over the age of 80 with diseases and disorders of the nervous system and the respiratory system.

The results from the Mann-Whitney and the Welch test indicate that all of the risk cells are statistically different with respect to the location of the distribution. Two of the risk cells are not statistically different with respect to the mean of the distribution. This is risk cell 20 and risk cell 24.

The average benefit paid for a hospital case where an individual is diagnosed with a pressure ulcer, on a risk-adjusted and weighted basis, is 3.30 times the average benefit paid for a hospital case where an individual is not diagnosed with a pressure ulcer. This is weighted by the total number of hospital cases in each risk cell. The average multiplicative factor is 2.54 on an unadjusted and unweighted basis.

This result is validated using the diagnosis of a pressure ulcer as an explanatory variable in model 3. The results from this model show that the diagnosis of a pressure ulcer is expected to increase the benefit paid for a hospital case.

This difference could be as a result of many factors, including differences in the length of stay. In this research, individuals that are diagnosed with a pressure ulcer have, on average, 21 days in hospital compared to 8 days, on average, for individuals that are not diagnosed with a pressure ulcer.

Using these results, the average benefit paid for a hospital case where an individual is diagnosed with a pressure ulcer is R130 676 more than the average benefit paid for a hospital case where an individual is not diagnosed with a

pressure ulcer. The analysis of this linked dataset shows that individuals are diagnosed with a pressure ulcer in 0.45% of all hospital cases. Assuming that this linked dataset is representative of the industry, this could result in an additional R1.4 billion in benefits paid from medical schemes over a period of one year (Council for Medical Schemes, 2016). The risk adjustment in this research, however, does not account for all factors that drive the variation in the benefit paid and this is therefore not an accurate estimate of the impact on the industry. The underlying demographic profile of individuals included in this research differs from all individuals in the industry. The prevalence of pressure ulcers will therefore vary across the industry. This also contributes to the inaccuracy of the estimate.

The AHRQ PSI methodology only uses the secondary diagnosis to identify hospital cases where an individual is diagnosed with a pressure ulcer. Figure 6.2 replicates this methodology and also shows the distribution of the average benefit paid for a hospital case where an individual is diagnosed with a pressure ulcer compared to the average benefit paid for a hospital case where an individual is not diagnosed with a pressure ulcer for all risk cells.

6.2.2 Analysis of the average benefit paid including the secondary diagnosis

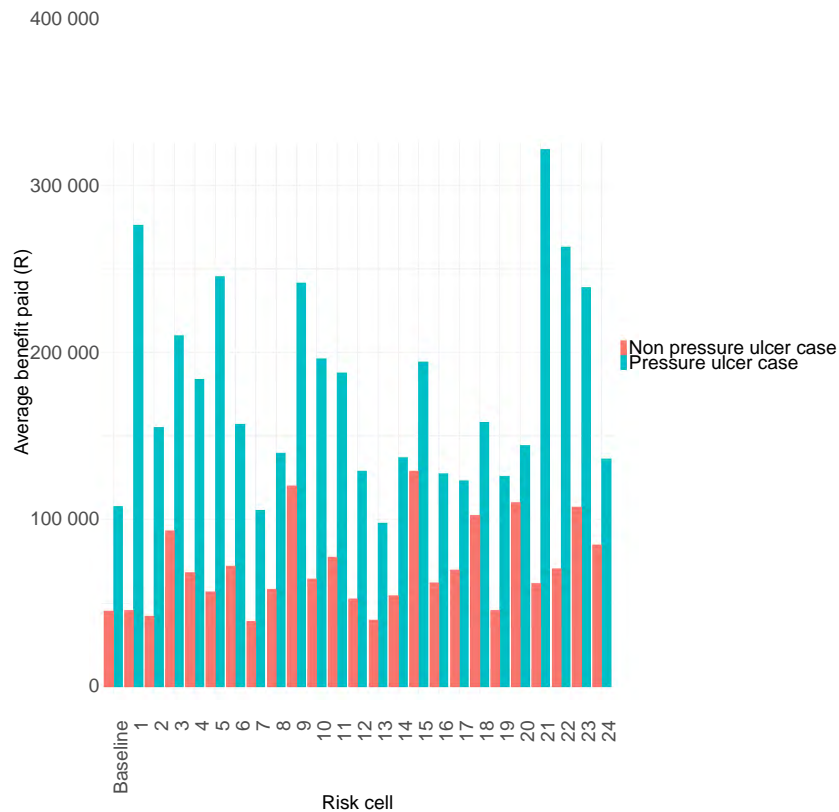


Figure 6.2: Distribution of the average benefit paid by risk cell including the secondary diagnosis

Figure 6.2 shows that there are four risk cells where the average benefit paid is different to the average benefit paid in Figure 6.1. This is namely risk cells: 2, 12, 13 and 19. This is because there are 107 hospital cases excluded from these results but that are included in the results shown in Figure 6.1. The pressure ulcer diagnosis code for these hospital cases indicates that it is only a primary diagnosis.

The risk cells in Figure 6.2 with the largest and smallest variation are the same as those in Figure 6.1.

The average benefit paid for a hospital case where an individual has either a secondary diagnosis or both a primary and secondary diagnosis of a pressure ulcer, on a risk-adjusted and weighted basis, is 3.31 times the average benefit paid for a hospital case where an individual has no diagnosis of a pressure ulcer. This is also weighted by the total number of hospital cases in each risk cell. The average multiplicative factor is 2.57 on an unadjusted and unweighted basis.

Grouping of the hospital cases by MDC, instead of by risk cell, is done in section 6.2.3. These results therefore use a grouper to risk-adjust the results. Figure 6.3 shows the distribution of the average benefit paid for a hospital case where an individual is diagnosed with a pressure ulcer compared to the average benefit paid for a hospital case where an individual is not diagnosed with a pressure ulcer by MDC. This figure includes hospital cases where the pressure ulcer diagnosis code indicates either a primary diagnosis, a secondary diagnosis or both diagnoses.

6.2.3 Analysis of the average benefit paid by MDC

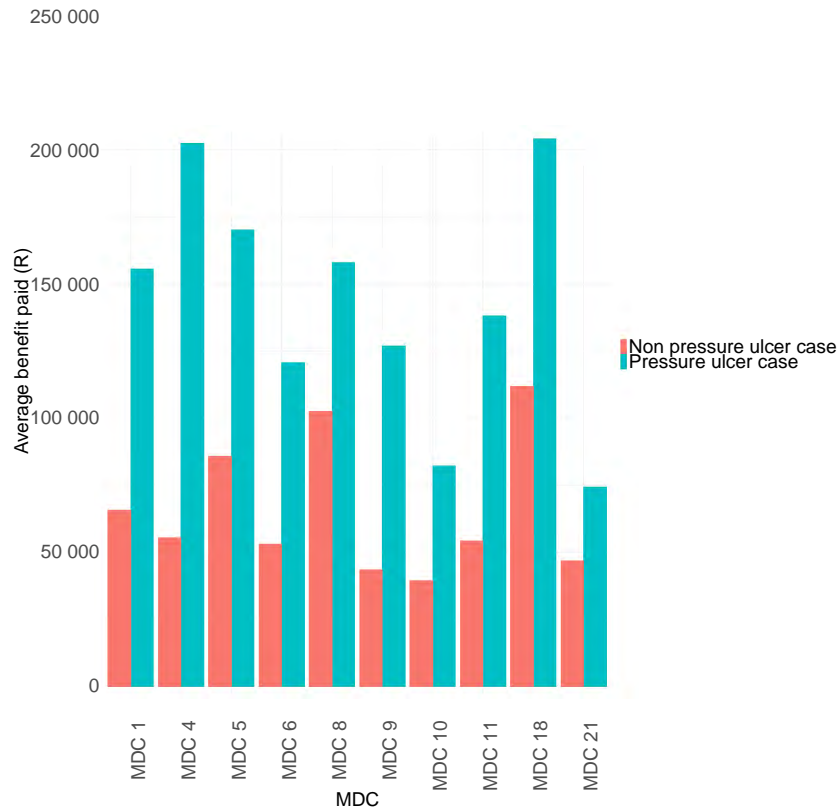


Figure 6.3: Distribution of the average benefit paid by MDC

Figure 6.3 shows that MDC 4 has the largest variation in the average benefit paid. This MDC includes hospital cases where the individual has diseases and disorders of the respiratory system. In this MDC, the average benefit paid for a hospital case where an individual is diagnosed with a pressure ulcer is 3.65 times the average benefit paid for a hospital case where an individual is not diagnosed with a pressure ulcer.

Figure 6.3 shows that the smallest variation in the benefit paid is for MDC 8. This MDC includes hospital cases where the individual has diseases and

disorders of the musculoskeletal system and connective tissue. In this MDC, the average benefit paid for a hospital case where an individual is diagnosed with a pressure ulcer is 1.54 times the average benefit paid for a hospital case where an individual is not diagnosed with a pressure ulcer.

The average benefit paid for a hospital case where an individual is diagnosed with a pressure ulcer, on a risk-adjusted and weighted basis, is 2.82 times the average benefit paid for a hospital case where an individual is not diagnosed with a pressure ulcer. Risk adjustment is done by grouping the hospital cases by MDC. This is weighted by the total number of hospital cases in each MDC.

The benefit paid for high-cost hospital cases is top-coded in Figures 6.1 to 6.3 because of the exclusion of outlier hospital cases in the statistical modelling. An analysis of the top ten high-cost hospital cases is shown in section 6.2.4 to quantify the financial impact of these hospital cases.

6.2.4 Analysis of the average benefit paid for high-cost hospital cases

The linked dataset includes 337 hospital cases where an individual is diagnosed with a pressure ulcer and where the benefit paid for the hospital case is greater than R664 814, before the benefit paid is top-coded. These hospital cases represent 9.11% of all hospital cases where an individual is diagnosed with a pressure ulcer. The distribution of the benefit paid for these hospital cases, before the adjustments are applied to the linked dataset, is shown in Figure 6.4. This figure includes hospital cases where the pressure ulcer diagnosis code indicates either a primary diagnosis, a secondary diagnosis or both diagnoses.

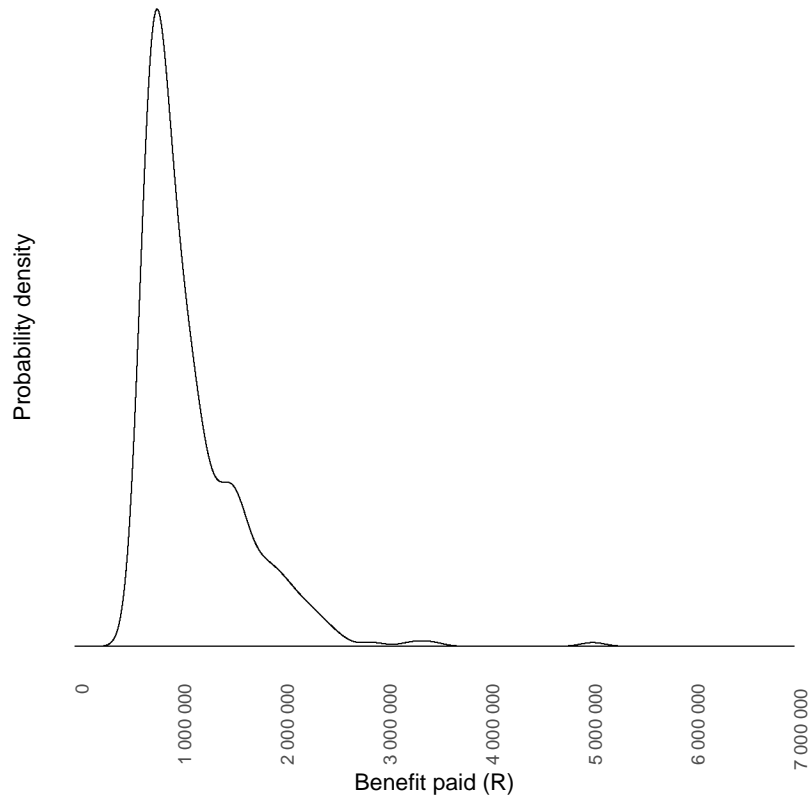


Figure 6.4: Distribution of the benefit paid for high-cost hospital cases where an individual is diagnosed with a pressure ulcer

Figure 6.4 shows the positively skewed nature of the distribution of the benefit paid where 27 of these high-cost hospital cases have a benefit paid that is greater than R2 000 000. The average benefit paid for these high-cost hospital cases is R1 219 252. The top 10 high-cost hospital cases have a benefit paid that is greater than R2 375 000. These hospital cases are described in Table 6.1.

Table 6.1: Description of the high-cost hospital cases

Case	Gender	Age-band	MDC
1	Female	0 - 12 months	Transplants and critical care
2	Female	1-9	Transplants and critical care
3	Female	50-59	Transplants and critical care
4	Male	20-29	Infectious and parasitic diseases
5	Male	30-39	Diseases and disorders of the nervous system
6	Male	60-69	Transplants and critical care
7	Male	60-69	Diseases and disorders of the respiratory system
8	Male	60-69	Diseases and disorders of the digestive system
9	Male	80+	Transplants and critical care

Table 6.1 includes two hospital cases in case 6 because there are two individuals that have the same risk profile and the benefit paid for their hospital case is greater than R2 375 000.

Figure 6.5 shows the distribution of the average benefit paid for these hospital cases compared to the average benefit paid for hospital cases where an individual is not diagnosed with a pressure ulcer. The hospital cases included in Figure 6.5 where the individual is not diagnosed with a pressure ulcer only include the hospital cases where the benefit paid is greater than or equal to R664 814 before these values are top-coded. This ensures that the comparisons are done on a like-for-like basis. There are 3 825 hospital cases where the individual is not diagnosed with a pressure ulcer and the benefit paid for the hospital case is greater than or equal to R664 814.

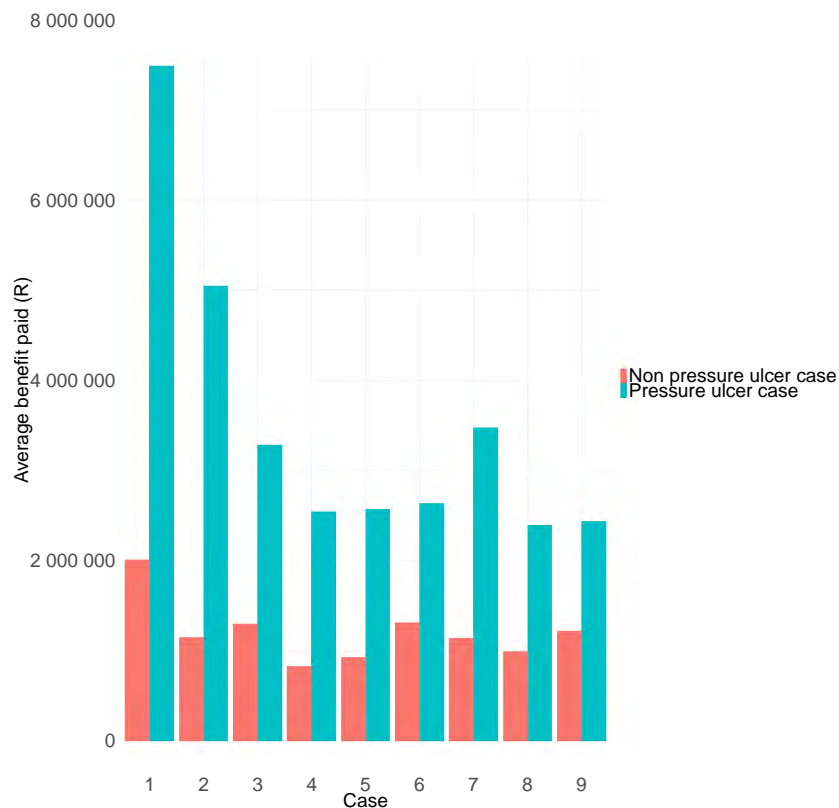


Figure 6.5: Distribution of the average benefit paid by high-cost hospital case

Figure 6.5 shows that the largest variation in the average benefit paid is for case 2. The benefit paid for the hospital case where the individual is diagnosed with a pressure ulcer is 4.38 times the average benefit paid for a hospital case where an individual is not diagnosed with a pressure ulcer. The benefit paid for the hospital case where the individual is diagnosed with a pressure ulcer is R5 041 258. The smallest variation in the benefit paid is for case 9. The benefit paid for the hospital case where the individual is diagnosed with a pressure ulcer is 1.99 times the average benefit paid for a hospital case where an individual is not diagnosed with a pressure ulcer.

High-cost cases are complex and there are many factors that can explain

the variation in the benefit paid. These factors are not accounted for and therefore these results are an inaccurate estimate of the impact of the diagnosis of a pressure ulcer on the benefit paid for the hospital case.

Chapter 7

Discussion and conclusion

7.1 Introduction

The main objective of this research was to estimate the financial implications of pressure ulcers in private hospitals in South Africa on a risk-adjusted basis. The results show that the average benefit paid for a hospital case where an individual is diagnosed with a pressure ulcer is 3.3 times the average benefit paid for a hospital case where an individual is not diagnosed with a pressure ulcer, on a risk-adjusted and weighted basis. The results also show that pressure ulcers increase the benefit paid for a hospital case when the analysis is done by MDC and for high-cost hospital cases.

Pressure ulcers are used as an outcome measure of quality of care relating to adverse events. The financial implications of this event is used to estimate the cost of poor quality of care. These results, however, are an under-estimate of the total financial implications of poor quality of care on the medical scheme industry because pressure ulcers are a single metric amongst the many measures that can be used to assess quality of care in private hospitals (Agency for Healthcare Research and Quality, 2015).

This research is relevant in South Africa because the quality of care provided by hospitals is under scrutiny given the concerns raised by the HMI (Medical Brief, 2015; Bateman, 2017). This research therefore describes an

outcome measure that can be used by hospitals to quantify quality of care. Pressure ulcers increase the benefit paid for a hospital case and therefore reducing pressure ulcers, with consideration for the costs of preventing pressure ulcers, can help managed care organisations to meet their aim of delivering cost-effective and high quality healthcare services (Health Market Inquiry, 2018). Managed care organisations can achieve this when they establish a network of hospitals or when they negotiate with hospitals on their reimbursement (Actuarial Society of South Africa, 2017a).

This research is therefore important for a number of stakeholders including: private hospitals, individuals that deliver healthcare services at private hospitals, medical schemes, the managed care organisations of medical schemes and the individuals that belong to medical schemes (Still, 2016; Health Market Inquiry, 2018).

There are, however, a number of limitations of the results in this research that should be considered.

7.2 Advantages and disadvantages of using outcomes as a quality of care dimension

Outcomes were considered as the most important dimension to measure, compared to structure and process, when assessing quality of care, given the frameworks proposed by Donabedian and Porter (Donabedian, 2005; Porter, 2010). The importance of measuring outcomes in South Africa has been recognised in the annual reports from the three large hospital groups (Life Group, 2017; Mediclinic, 2018; Netcare Limited, 2016). This has also been recently recognised by the HMI because their recommendations include the establishment of a system to report on quality with a focus on the measurement of outcomes (Health Market Inquiry, 2018).

There are many advantages of using outcome measures. They are a measure of what happens to an individual when they leave the hospital (Porter, 2010; Donabedian, 2005). They can help the hospital to improve by

creating a feedback process for the individual that delivers healthcare services at the hospital (Dale *et al.*, 2016).

In South Africa, specifically, managed care organisations could use these measures to provide feedback to hospitals when they establish a network of hospitals or when they negotiate with them on the amount that they will reimburse them for the services that they provide (Actuarial Society of South Africa, 2017a). They could, for example, establish a network of hospitals based on their outcome measures. They could use the outcome measures when negotiating the fee that they will pay hospitals for the services that they provide. They could argue for a lower fee for hospitals that perform relatively worse in terms of their outcome measures. The results in this research show that the diagnosis of a pressure ulcer, a negative result of an outcome measure, increases the cost of care. Managed care organisations could recover these additional costs by negotiating for a lower fee.

Both of these techniques could reduce the amount that they will need to pay for these hospital cases. This would also encourage hospitals to improve the results of their outcome measures. Poor results of outcome measures have a non-financial impact on both the individuals that receive healthcare services and the individuals that provide healthcare services, as described for pressure ulcers in this research. Improved results of outcome measures would therefore be beneficial for both of these parties.

It is difficult to identify outcomes because the collection of administrative data in South Africa is structured to manage cases and provide reimbursement (Actuarial Society of South Africa, 2017d,a). The data are therefore not collected to measure quality of care. It is therefore not possible to accurately measure these outcomes. Outcomes are also likely to be affected by many factors and it is not possible to account for all of these factors with risk adjustment. The number of factors accounted for in risk adjustment is limited by the variables that are available in the linked dataset.

There are several reasons for choosing pressure ulcers as a measure of an adverse event. There are, however, disadvantages of using this adverse event.

7.3 Advantages and disadvantages of using pressure ulcers as an example of an adverse event

Pressure ulcers are chosen as a measure of an adverse event in this research. They are largely preventable and should, in most hospital cases, never occur in hospital (National Quality Forum (NQF), 2011; Black *et al.*, 2011). The incidence of a pressure ulcer therefore indicates poor quality of healthcare services. They are included in the patient safety measures defined by AHRQ and are included in the annual reports published by the three large hospital groups in South Africa (Life Group, 2017; Mediclinic, 2018; Netcare Limited, 2016; Agency for Healthcare Research and Quality, 2018a). They are recognised as a burdensome adverse event and result in both financial and non-financial implications for the individual receiving healthcare services and the individual delivering healthcare services (Institute for Healthcare Improvement, 2017; Brem *et al.*, 2011; Bottle and Aylin, 2009; Bennett *et al.*, 2004; Russo *et al.*, 2008; Allman *et al.*, 1999; Slawomirski *et al.*, 2017). They are identifiable in the linked dataset used in this research (Quan *et al.*, 2008).

The results in this research show that, on a risk-adjusted basis, the diagnosis of a pressure ulcer increases the average benefit paid for a hospital case. This is in line with the literature reviewed that highlights the financial implications of pressure ulcers. This adverse event can therefore be used to measure quality of care.

In the linked dataset used in this research, however, the number of hospital cases where an individual is diagnosed with a pressure ulcers is low and the restriction on the number of hospital cases per group in the application of risk adjustment further limits the number of hospital cases included in the results. The literature reviewed highlights that older individuals are more likely to develop pressure ulcers. This is seen in the results because the youngest individuals included in the risk cells are in the age-band 40-49. This choice of outcome measure therefore limits the credibility of the results (The Actuarial

Education Company, 2017b).

There are other adverse events included in the annual reports from the three large hospital groups (Life Group, 2017; Mediaclinic, 2018; Netcare Limited, 2016). The diagnosis and procedure codes to identify these events, however, are not available using the PSIs from AHRQ (Quan *et al.*, 2008). Patient-reported outcome measures are relevant given the renewed focus of healthcare on the needs of the individual but the data are not available for this research (Berg, 2015; BMJ Outcomes, 2015b).

The estimate of the financial implications of pressure ulcers therefore only represents a proportion of the financial implications of poor quality of care. Further research to estimate the financial implications of all adverse events would therefore be useful.

Further research to compare the risk-adjusted prevalence of pressure ulcers between hospitals could also be done. This would help to assess the feasibility of using pressure ulcers as an example of an adverse event to assess the quality of care. This could also be used to determine the factors that cause the variation in the risk-adjusted prevalence of pressure ulcers.

These estimates are also limited by the data that are available and the adjustments applied to the linked dataset.

7.4 Limitations of the linked dataset and the adjustments applied to the linked dataset

Additional information is included in the linked dataset by summarising the diagnosis and procedure codes with a DRG. The DRG used summarises the diagnosis and procedure codes provided in the data. The accuracy of this classification is limited by the accuracy of the diagnosis and procedure codes that are included in the data provided.

The adjustments applied to the linked dataset include an adjustment to the distribution of the benefit paid using a price index. This is done to account for the variation in the benefit paid by calendar year. This is

constructed using values in the linked dataset. The medical component of CPI is publicly available but the methodology used to define this index is not appropriate to use in this research (Actuarial Society of South Africa, 2017d). The construction of a price index is therefore suitable.

The use of a price index, however, means that the assumptions of this index have an impact on the estimates of the financial implications of pressure ulcers. The price index assumes that the mix of fees at a base DRG level remains constant in each year. This is limited because, for example, the index does not allow for changes in the length of stay where a fee would be charged for each day at the hospital. Using datasets over a longer period of time would improve the credibility of the results. A price index would need to be used to adjust the data over this period of time. The comparisons would therefore be less relevant because the assumptions of the price index would have a larger impact on the estimates of the financial implications (The Actuarial Education Company, 2017b). The price index therefore limits the volume of data used because of the impact of using this index over a number years.

Diagnosis codes in the linked dataset are used to identify AHRQ-exclusion hospital cases because these individuals are more likely to develop pressure ulcers and therefore have a relatively worse risk profile (Agency for Healthcare Research and Quality, 2006). The diagnosis codes in South Africa, however, are used for case management and reimbursement (Actuarial Society of South Africa, 2017d,a). The diagnosis codes for these conditions might therefore not be included if these codes are not needed for either of these purposes. The number of AHRQ-exclusion hospital cases in this research might therefore be under-estimated. The low number of hospital cases identified in this research limits the ability of this explanatory variable to explain the variation in the benefit paid.

The original values of the benefit paid are adjusted by excluding outlier hospital cases. This limits the estimates of the implications of pressure ulcers, as discussed in section 7.7.

An adjustment is made to identify hospital cases where an individual is

diagnosed with a pressure ulcer. The identification of these hospital cases is also limited by the purpose of the diagnosis coding system in South Africa. The pressure ulcer diagnosis code might not be included in the data if this code is not needed for either case management or reimbursement. The managed care organisation relies on receiving updates from either the individual receiving healthcare services or the individual delivering healthcare services during the period of the hospital case¹. The pressure ulcer diagnosis code might therefore not be included in the data if it developed during the period of the hospital case and the managed care organisation was not informed of this. For example, a Stage I pressure ulcer might not be recorded if there is no specific fee charged to manage this pressure ulcer. Further research that includes additional data sources could improve the ability to identify hospital cases where an individual is diagnosed with a pressure ulcer.

The AHRQ PSI methodology is used to identify hospital cases where an individual is diagnosed with a pressure ulcer. This methodology uses the secondary diagnoses so that only hospital cases where an individual developed a pressure ulcer at hospital are identified (Agency for Healthcare Research and Quality, 2006). In this research, however, both the primary and secondary diagnosis are used because the clinical coding rules are different in South Africa. It is therefore not possible to accurately identify hospital cases where an individual developed a pressure ulcer at the hospital.

In this linked dataset, however, the number of hospital cases where the diagnosis code indicates that it is only a primary diagnosis is relatively low. This does, however, highlight the importance of developing a system to record adverse events so that these can be accurately identified.

Validation of the number of hospital cases identified using the administrative data is limited. Voluntary reports, medical records and charts are not available for this research. Even if the medical records were available, it would not have been possible to use the IHI Global Trigger Tool because this method requires feedback from a team of at least three individuals (Griffin and Resar, 2009).

¹L Whitelaw 2018, personal communication, 28 August.

Clinical data from hospitals to supplement data from the administrator would help to improve the accuracy of the identification of this adverse event.

There are further limitations of using the AHRQ PSI methodology to identify hospital cases where an individual is diagnosed with a pressure ulcer.

The restriction on the minimum number of days in hospital is lowered to three days in hospital compared to the five days used in the 2006 version of the definition. This is done to reflect the latest changes in the definition and ensures that there are a sufficient number of hospital cases to ensure that the results are credible (The Actuarial Education Company, 2017b). A lower number of hospital cases where an individual is diagnosed with a pressure ulcer would have been identified if the restriction on the minimum number of bed-days was increased to five. A minimum of five days in hospital, however, would have been more accurate because it would have been more likely that the pressure ulcer developed at hospital (Agency for Healthcare Research and Quality, 2006; Defloor and De Schuijmer, 2000).

It is not possible to account for the procedure codes used in the AHRQ PSI methodology given the different coding systems used in South Africa (Actuarial Society of South Africa, 2017d; Agency for Healthcare Research and Quality, 2006). It is also not possible to identify the previous healthcare setting of the individual given the nature of the final linked dataset used in this research. The financial implications will therefore be an under-estimate if the individual was either admitted from a long-term care hospital or transferred from an acute care hospital.

This linked dataset is used for statistical modelling but there are limitations of the methodology used for statistical modelling.

7.5 Limitations of the statistical modelling for risk adjustment

The methodology followed to fit statistical distributions to the distribution of the benefit paid, the analysis of the variables and the model-building process

could have been improved by using additional statistical tests. This, however, would have resulted in a number of additional results that would need to be considered. Judgement would therefore need to have been applied when weighting the relevance of these results and the results would therefore have been less valid.

Additional explanatory variables could have been used in the statistical model. Initial conditions, for example, would have been in line with the recommendations of Porter (Porter, 2010). These initial conditions could include the presence of multiple chronic conditions. These chronic conditions could be included in further research. The inclusion of the AHRQ-exclusion indicator is limited, as discussed, in its ability to identify diagnoses that are present on admission. Other explanatory variables such as the family history of the individual or their lifestyle could affect the benefit paid for their hospital case (Duncan, 2011). Clinical information from hospitals could have been used to supplement the information provided for these hospital cases to identify additional explanatory variables. These data are not available and therefore these factors have not been accounted for. The estimate of the financial implications of pressure ulcers is therefore not accurate.

Additional explanatory variables in the statistical model, however, would have resulted in a less parsimonious model (Dobson and Barnett, 2008). This could have affected the application of risk adjustment if the statistical modelling process identified additional factors that could explain the variation in the benefit paid for a hospital case. This would have resulted in fewer hospital cases per group which would therefore have limited the total number of hospital cases included in the analysis. This would have limited the credibility of the results (The Actuarial Education Company, 2017b).

The plots used to assess the results of the statistical models do not have a single statistic to summarise these results and are therefore limited by the judgement applied when analysing these plots. This included the interpretation of the residual plots and the histogram of the residuals. The cross-validation results indicate that the Gaussian distribution fitted to the

logarithmic transformation of the distribution of the benefit paid had the best predictive accuracy. This improves confidence in the judgement applied in the statistical model building process.

The results from the statistical modelling are used in the application of risk adjustment. Other methods of applying risk adjustment that do not use statistical modelling, however, were considered.

7.6 Additional considerations for the methodology to apply risk adjustment

Statistical modelling is used as the methodology for risk adjustment in this research. This is because there are a large number of hospital cases that are available and it is therefore possible to use this form of risk adjustment. Statistical modelling ensures that the results are relevant for the individuals that are included in this linked dataset. Statistical tests are also used given the limited results of the models. Using a grouper to create risk cells would have used factors that might not have been relevant for individuals in this linked dataset. The results of this grouper, however, are used in the statistical modelling because this summarises the clinical characteristics of the hospital cases (Insight Actuaries and Consultants, 2016; Duncan, 2011).

Using a propensity score as the methodology for risk adjustment is not suitable for this research. This methodology is used for observational studies where there is an intervention (Iezzoni, 2012). The diagnosis of a pressure ulcer in a hospital case could have been used as the response variable in the logistic regression model. The hospital cases where an individual develops a pressure ulcer are 0.45% of all hospital cases. The results of a statistical model using the diagnosis of a pressure ulcer as the response variable would therefore have been less credible compared to the statistical model where all hospital cases are included in the response variable. There are, however, additional considerations of using statistical modelling for risk adjustment.

This methodology includes a restriction on the number of hospital cases

per group. A change in the minimum number of hospital cases per group would have affected the results. An increase in the number of hospital cases per group would have improved the credibility of the results within each risk cell but would have resulted in fewer risk cells which would have limited the credibility of the results (The Actuarial Education Company, 2017b). A decrease in the number of hospital cases per group would have worsened the credibility of the results within each risk cell but would have resulted in more risk cells which would have improved the credibility of the results (The Actuarial Education Company, 2017b).

This methodology also includes two statistical measures to compare the distribution of the benefit paid between different groups when deciding on the groups that should be combined to create risk cells. The inclusion of more measures would have improved the accuracy of the results. This, however, would have resulted in a number of combinations of groups that would need to be considered when deciding on the groups to combine to form risk cells.

These risk cells are used to estimate the financial implications of pressure ulcers. There are limitations of these estimates. Other implications of pressure ulcers should also be considered.

7.7 Limitations of the estimates of the implications of pressure ulcers

The results indicate that, irrespective of the position of the pressure ulcer diagnosis code, the average benefit paid for a hospital case where an individual is diagnosed with a pressure ulcer is 3.3 times the average benefit paid for a hospital case where an individual is not diagnosed with a pressure ulcer, on a risk-adjusted and weighted basis.

Using both the primary and the secondary diagnosis code to identify these hospital cases, however, limits the accuracy of the estimation of the financial implications of pressure ulcers. The individual could have developed the pressure ulcer at home and the estimate of the financial implications could

either be an under-estimate or an over-estimate. The benefit paid for the hospital case could be an under-estimate if there are additional costs incurred in treating the pressure ulcer at home that are not incurred in hospital. The benefit paid for the hospital case, however, could be an over-estimate if the individual is admitted with a more severe pressure ulcer that would require more resources at the hospital. Further research could include additional data sources to describe the previous treatment that the individual received. The financial implications of pressure ulcers could also be an over-estimate because the comparison that is made assumes that no-one will develop a pressure ulcer at hospital. The literature review describes pressure ulcers as being preventable but also shows that these do occur in hospital. This is therefore an over-estimate of the financial implications of pressure ulcers.

The amount that the individual claims from the medical scheme could have been used instead of the amount that the medical scheme reimbursed. The MSA in South Africa, however, indicates that minimum benefits are covered and therefore the difference in these two values should not be large because the minimum benefits include benefits for healthcare services and goods in hospital (Department of Health, 1998).

The results, only using the MDC to group the hospital cases, indicate that the average benefit paid for a hospital case where an individual is diagnosed with a pressure ulcer is 2.82 times the average benefit paid for a hospital case where an individual is not diagnosed with a pressure ulcer, on a risk-adjusted and weighted basis. The lower estimate using the MDC highlights the importance of using statistical modelling for risk adjustment. The inclusion of additional variables in the risk cells shows that there are other factors that drive the variation in the benefit paid for a hospital case. Including these factors allows for comparisons between groups that are expected to be homogeneous with respect to the distribution of the benefit paid.

A managed care organisation, however, might find it more useful to use the results grouped by MDC. A classification of their hospital cases by MDC could be used to estimate the financial impact of pressure ulcers on their

scheme. A managed care organisation, however, would need to consider the additional costs incurred to prevent the incidence of pressure ulcers.

This includes additional costs to purchase items and the additional healthcare services needed to prevent the incidence of pressure ulcers. The managed care organisation should also consider the non-financial implications for both individuals that belong to their scheme and individuals delivering healthcare services when evaluating the total implications of pressure ulcers.

The financial implications of these pressure ulcers could also be underestimated because outlier hospital cases are excluded, given the impact of these hospital cases on the statistical modelling process. These could have increased or decreased the estimate of the financial implications of pressure ulcers. A relatively higher number of top-coded hospital cases where the individual is diagnosed with a pressure ulcer, compared to other hospital cases, would have increased the estimate of the financial implications of pressure ulcers. Likewise, a relatively higher number of trimmed hospital cases where the individual is diagnosed with a pressure ulcer would have decreased the estimate of the financial implications of pressure ulcers. An analysis of the top ten high-cost hospital cases quantifies the impact of the hospital cases that are top-coded.

The benefit paid for the high-cost hospital cases where an individual is diagnosed with a pressure ulcer is greater than the benefit paid for high-cost hospital cases where an individual is not diagnosed with a pressure ulcer. The impact of these hospital cases on the overall multiplicative factor depends on the relative impact of these cases on each risk cell and is not quantified.

Additional estimates of the financial implications of pressure ulcers could have been considered. Porter recommends that the financial implications should be measured longitudinally (Porter, 2010). This is not done in this research given the nature of the medical scheme environment. Individuals can choose to change their benefit option or leave a medical scheme (Actuarial Society of South Africa, 2017d). Data from all medical schemes in South Africa are not available for this research and therefore the data might not be

available if the individual leaves the medical scheme.

7.8 Conclusion

The estimate of the financial implications of pressure ulcers shows that the multiplicative factor is always greater than one. This indicates that the benefit paid for a hospital case where an individual is diagnosed with a pressure ulcer is always greater than the benefit paid for a hospital case where an individual is not diagnosed with a pressure ulcer. This result does not change when the position of the diagnosis code used in the analysis is changed or when the grouping is done by MDC. These same results are also shown for high-cost hospital cases.

The total impact of pressure ulcers on the medical scheme industry is estimated at R1.4 billion. Pressure ulcers are a single metric amongst the many measures that can be used to assess quality of care (Agency for Healthcare Research and Quality, 2015). The impact of poor quality of care on the medical scheme industry is therefore under-estimated.

These results are useful and indicate that pressure ulcers increase the benefit paid for hospital cases. Pressure ulcers can therefore be used as a measure of the quality of care provided by private hospitals. Managed care organisations can therefore use these results to meet their aim of delivering cost-effective and high quality healthcare services (Actuarial Society of South Africa, 2017a). This could be done by establishing a network of hospitals that have the lowest incidence of pressure ulcers or using this as a quality of care measure when they negotiate with hospitals to decide on the amount that the scheme will reimburse the hospitals for their services (Actuarial Society of South Africa, 2017a).

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Appendices

Appendix A

Description of the major diagnostic categories

Table A.1: Description of the major diagnostic categories (MDCs)

	Description
0	Transplants and critical care
1	Diseases and disorders of the nervous system
2	Diseases and disorders of the eye
3	Diseases and disorders of the ear, nose, mouth and throat
4	Diseases and disorders of the respiratory system
5	Diseases and disorders of the circulatory system
6	Diseases and disorders of the digestive system
7	Diseases and disorders of the hepatobiliary system and pancreas
8	Diseases and disorders of the musculoskeletal system and connective tissue
9	Diseases and disorders of the skin, subcutaneous tissue and breast
10	Endocrine, nutritional and metabolic diseases and disorders
11	Diseases and disorders of the kidney and urinary system
12	Diseases and disorders of the male reproductive system
13	Diseases and disorders of the female reproductive system
14	Pregnancy, childbirth and the puerperium
15	Newborns and other neonates
16	Diseases and disorders of the blood and blood forming organs and immunological disorders
17	Neoplastic disorders (haematological and solid neoplasms)
18	Infectious and parasitic diseases
19	Mental diseases and disorders
20	Alcohol/drug use and alcohol/drug induced organic mental disorders
21	Injuries, poisoning and toxic effects of drugs
22	Burns
23	Factors influencing health status and other contacts with health services

Appendix B

Measurement of the fit of the statistical distributions to the distribution of the benefit paid

B.1 QQ plots and plots of empirical and fitted distributions

B.1.1 Gamma distribution

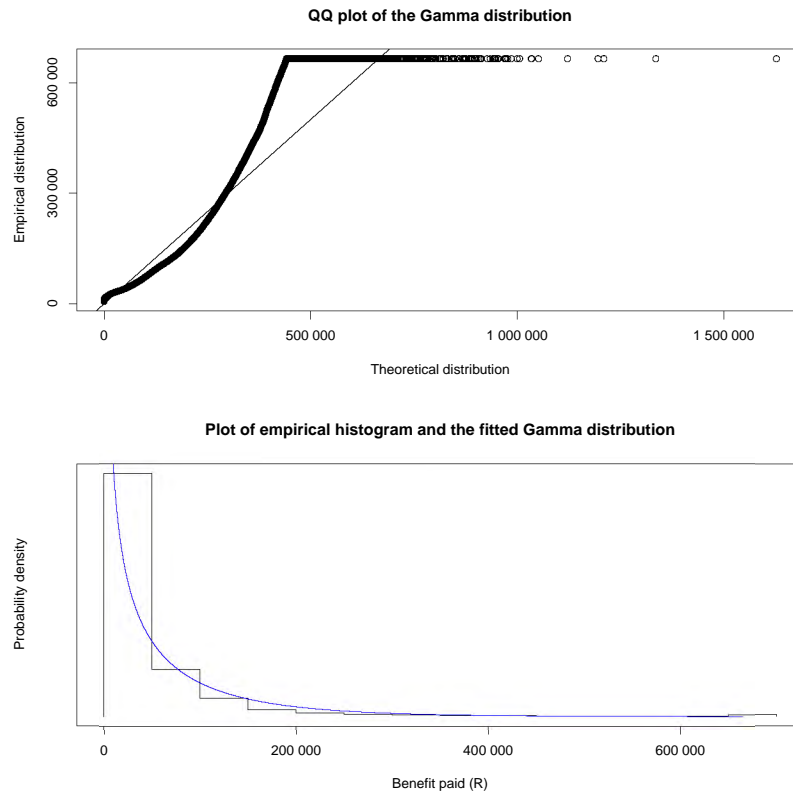


Figure B.1: Plots used to assess the fit of the Gamma distribution

B.1.2 Inverse Gaussian distribution

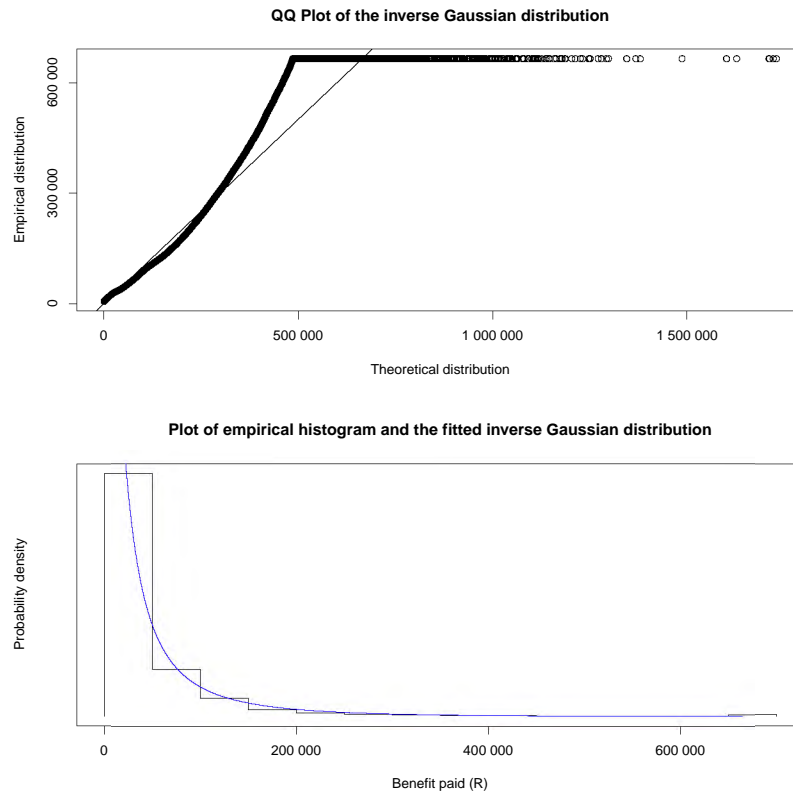


Figure B.2: Plots used to assess the fit of the inverse Gaussian distribution

B.1.3 Gaussian distribution

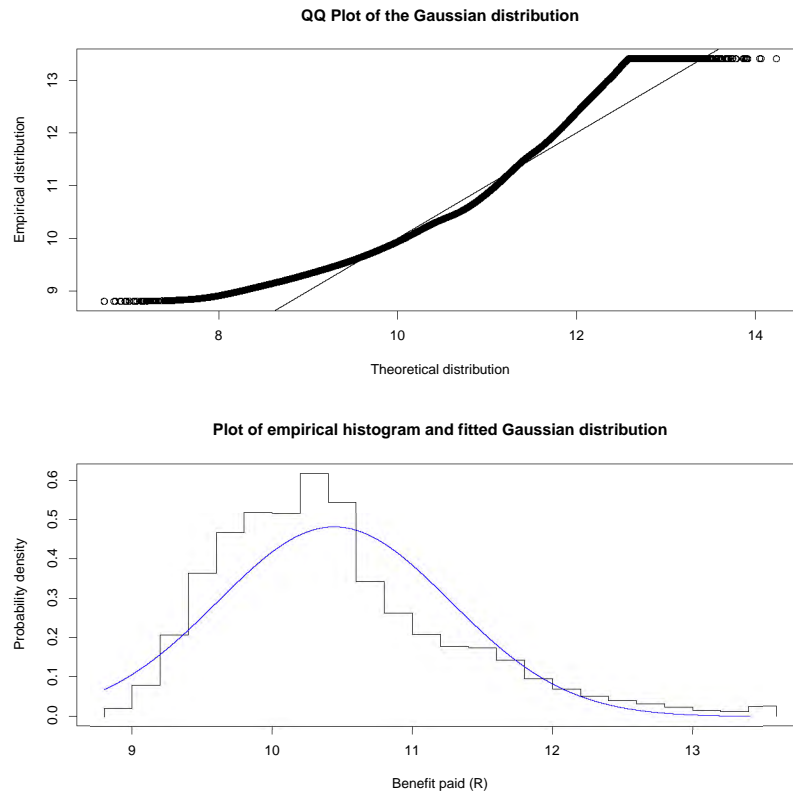


Figure B.3: Plots used to assess the fit of the Gaussian distribution

Appendix C

Assessing the results of the statistical models

C.1 Model 1

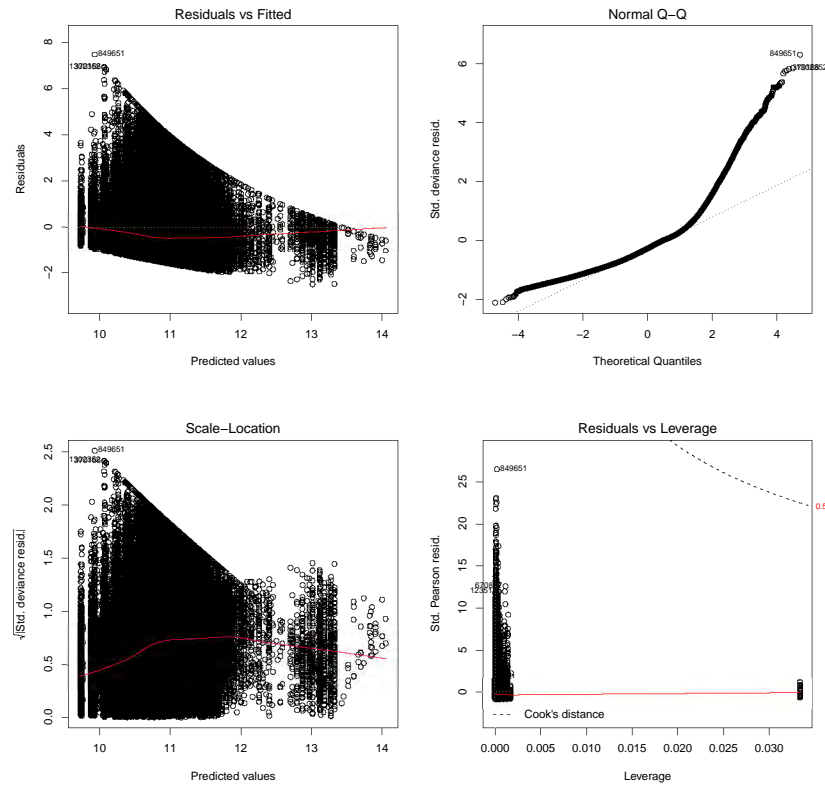


Figure C.1: Plots used to assess Model 1

C.2 Model 2

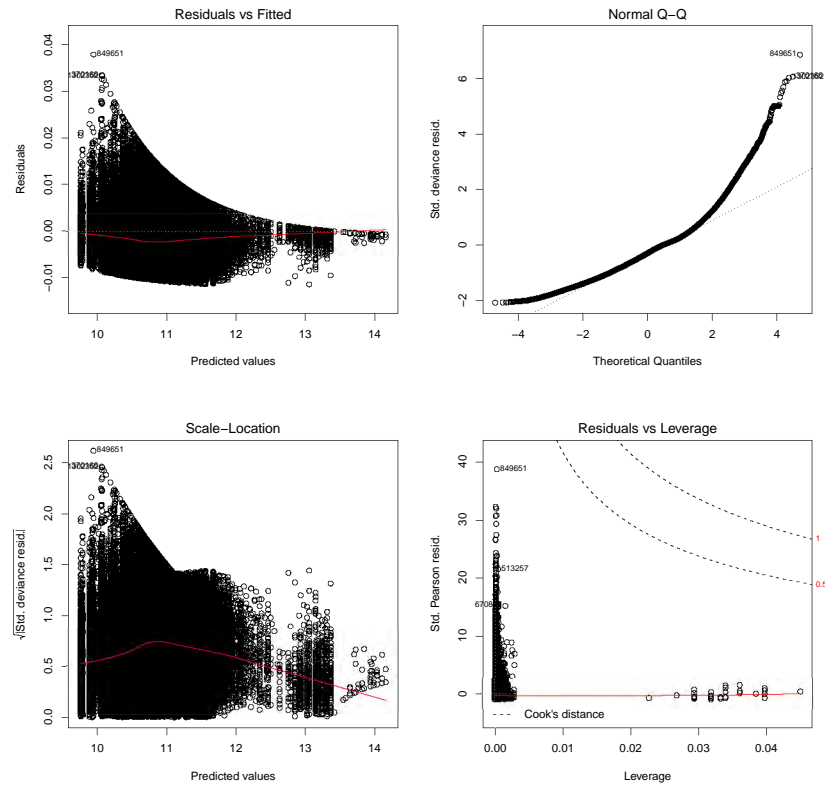


Figure C.2: Plots used to assess Model 2

C.3 Model 3

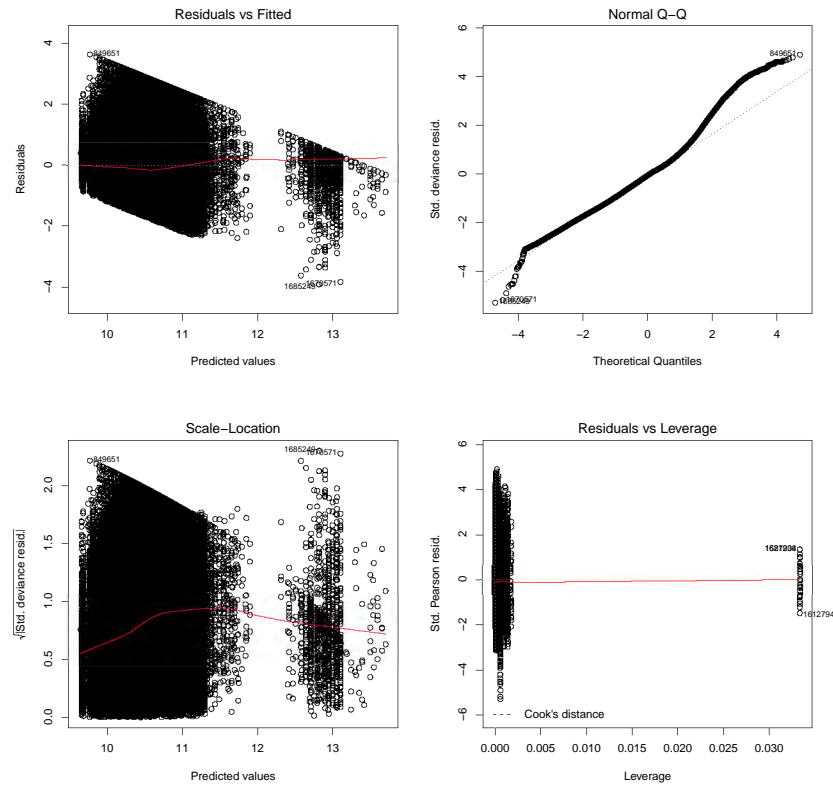


Figure C.3: Plots used to assess Model 3

Appendix D

Description of the risk cells

Table D.1: Description of the baseline risk cell

Gender	Age-band	MDC
Female	80+	Diseases and disorders of the skin, subcutaneous tissue and breast
Female	60-69	Diseases and disorders of the skin, subcutaneous tissue and breast
Female	80+	Diseases and disorders of the eye
Female	80+	Mental diseases and disorders
Female	80+	Injuries, poisoning and toxic effects of drugs

Table D.2: Description of risk cell one

Gender	Age-band	MDC
Female	50-59	Diseases and disorders of the skin, subcutaneous tissue and breast
Male	50-59	Diseases and disorders of the skin, subcutaneous tissue and breast

Table D.3: Description of risk cell two

Gender	Age-band	MDC
Female	60-69	Diseases and disorders of the nervous system
Female	70-79	Diseases and disorders of the respiratory system

Table D.4: Description of risk cell three

Gender	Age-band	MDC
Female	50-59	Infectious and parasitic diseases

Table D.5: Description of risk cell four

Gender	Age-band	MDC
Female	60-69	Infectious and parasitic diseases
Male	60-69	Infectious and parasitic diseases

Table D.6: Description of risk cell five

Gender	Age-band	MDC
Female	70-79	Infectious and parasitic diseases

Table D.7: Description of risk cell six

Gender	Age-band	MDC
Female	80+	Infectious and parasitic diseases

Table D.8: Description of risk cell seven

Gender	Age-band	MDC
Female	40-49	Diseases and disorders of the respiratory system
Female	50-59	Diseases and disorders of the respiratory system

Table D.9: Description of risk cell eight

Gender	Age-band	MDC
Female	60-69	Diseases and disorders of the respiratory system

Table D.10: Description of risk cell nine

Gender	Age-band	MDC
Female	70-79	Diseases and disorders of the respiratory system

Table D.11: Description of risk cell ten

Gender	Age-band	MDC
Male	50-59	Diseases and disorders of the respiratory system

Table D.12: Description of risk cell 11

Gender	Age-band	MDC
Male	60-69	Diseases and disorders of the respiratory system

Table D.13: Description of risk cell 12

Gender	Age-band	MDC
Female	70-79	Diseases and disorders of the circulatory system

Table D.14: Description of risk cell 13

Gender	Age-band	MDC
Male	60-69	Diseases and disorders of the circulatory system
Male	70-79	Diseases and disorders of the circulatory system

Table D.15: Description of risk cell 14

Gender	Age-band	MDC
Female	80+	Diseases and disorders of the circulatory system

Table D.16: Description of risk cell 15

Gender	Age-band	MDC
Male	80+	Diseases and disorders of the circulatory system

Table D.17: Description of risk cell 16

Gender	Age-band	MDC
Female	70-79	Diseases and disorders of the digestive system
Female	80+	Diseases and disorders of the digestive system
Male	70-79	Diseases and disorders of the skin, subcutaneous tissue and breast

Table D.18: Description of risk cell 17

Gender	Age-band	MDC
Female	70-79	Endocrine, nutritional and metabolic diseases and disorders
Female	80+	Endocrine, nutritional and metabolic diseases and disorders
Male	40-49	Diseases and disorders of the skin, subcutaneous tissue and breast

Table D.19: Description of risk cell 18

Gender	Age-band	MDC
Female	80+	Diseases and disorders of the kidney and urinary system
Male	60-69	Diseases and disorders of the skin, subcutaneous tissue and breast

Table D.20: Description of risk cell 19

Gender	Age-band	MDC
Female	60-69	Diseases and disorders of the circulatory system
Female	70-79	Diseases and disorders of the nervous system

Table D.21: Description of risk cell 20

Gender	Age-band	MDC
Female	80+	Diseases and disorders of the nervous system
Male	80+	Diseases and disorders of the respiratory system

Table D.22: Description of risk cell 21

Gender	Age-band	MDC
Female	60-69	Diseases and disorders of the kidney and urinary system
Female	80+	Diseases and disorders of the respiratory system

Table D.23: Description of risk cell 22

Gender	Age-band	MDC
Female	60-69	Endocrine, nutritional and metabolic diseases and disorders

Table D.24: Description of risk cell 23

Gender	Age-band	MDC
Female	70-79	Diseases and disorders of the kidney and urinary system

Table D.25: Description of risk cell 24

Gender	Age-band	MDC
Female	80+	Diseases and disorders of the musculoskeletal system and connective tissue