

***A retrospective audit of the
clinical value
of routine chest radiograph
in the first 24 hours after
cardiac surgery
using medical records***

*Minor dissertation submitted to the University of Cape Town in partial
fulfilment of the requirements for*

Master of Medicine (MMed) in Anaesthesia

By

Dr. S .C. Nyoka-Mokgalong

Student number: NYKSIM001

FACULTY OF HEALTH SCIENCES
UNIVERSITY OF CAPE TOWN

The copyright of this thesis vests in the author. No quotation from it or information derived from it is to be published without full acknowledgement of the source. The thesis is to be used for private study or non-commercial research purposes only.

Published by the University of Cape Town (UCT) in terms of the non-exclusive license granted to UCT by the author.

Student Researcher

Dr. Simangele Cecilia Nyoka-Mokgalong BSc (UNIN) MBChB (Medunsa)
DA (SA)

Registrar

Department of Anaesthesia

Groote Schuur Hospital and University of Cape Town

Principal Investigator and Supervisor

Dr. Daniela Visu MD (Rom) Dip Obst (SA) DA (SA) FCA (SA)

Consultant Anaesthetist

Department of Anaesthesia

Groote Schuur Hospital and University of Cape Town

Co-investigator and Diagnostic Radiologist

Dr. Mariam Qonita Said-Hartley MBChB (UCT) FCRad (diagnostic) (SA)

Consultant Radiologist

Department of Radiology

Groote Schuur Hospital and University of Cape Town

Contents

	Page
<i>Declaration</i>	5
<i>Acknowledgments</i>	6
<i>List of abbreviations</i>	7
Abstract	8
1. Chapter One: Introduction	10
2. Chapter Two: Background	14
2.1. General information	
2.2. Complications following cardiac surgery	
2.3. Diagnosis of potential complications	
2.4. The need to investigate the investigations	
3. Chapter Three: Review of Literature	31
3.1. Objectives	
3.2. Search strategy	
3.3. Summary and interpretation of the literature	
3.4. Rationale for the study	
3.5. The need for further research	
4. Chapter Four: Aims and objectives	51
4.1. Aims	
4.2. Objectives	
5. Chapter Five: Methodology	54
5.1. Methodology	
5.2. Ethics approval	
5.3. Participants	

5.4. Consent	
5.5. Chest radiographs	
5.6. Time frame	
5.7. Challenges	
5.8. Assumptions	
5.9. Application of methodology	
6. Chapter Six: Thematic Analysis	74
6.1. Routine chest radiographs in different categories	
6.2. Research data analysis	
7. Chapter Seven: Results	77
7.1. Demographic data	
7.2. Chest radiography	
8. Chapter Eight: Discussion	82
8.1. Summary and data analysis	
8.2. Radiologist findings vs clinical findings	
8.3. Chest X-rays following removal of ICDs	
8.4. Radiological findings in minimally invasive cardiac surgery	
8.5. Chest radiographs and invasive devices	
8.6. The role of serial radiographs in evolving pathology	
8.7. Radiological findings in post PTB patients after cardiac surgery	
9. Chapter Nine: Conclusion	91
9.1. Reflections	
9.2. Limitations	
9.3. Recommendations	

Declaration

I, Dr. Cecilia Nyoka-Mokgalong, hereby declare that the work on which this dissertation/thesis is based is my original work (except where acknowledgements indicate otherwise) and has not been submitted before now, and in any form whatsoever, by myself or anyone else, to this University or any other educational institution for another degree.

I do acknowledge all sources used and cite these in the bibliography. There has been no infringement of publishers' copyright stipulations.

I understand that any breach of this declaration may result in non-acceptance of my paper by those concerned.

Further, I empower the University of Cape Town to reproduce/use, for the purpose of teaching or research, either the whole or any portion of the contents of this work in any manner whatsoever.

Signed by candidate

Signature:

Date: 2015/10/28

Acknowledgements and thanks

I would like to thank:

- *Dr. Daniela Visu, my supervisor, for her help in the choice of the research topic, as well as for her encouragement, understanding and continuous support;*
- *Dr. Qonita Said-Hartley, for all the time spent with me, especially after hours , looking at and interpreting chest radiographs;*
- *Professor Peter Zilla, for kindly allowing me access/use of the Groote Schuur Cardiothoracic Database;*
- *All the Groote Schuur Department of Anaesthesia Staff, for support, encouragement, and understanding;*
- *Professor Rob Dyer, who took some time off his busy schedule to streamline the wording of the proposal and his significant help in getting the wheels of red tape moving in facilitating the required permission from authorities to access medical records.*

My sincerest gratitude goes to Professor Justiaan Swanevelder for directing me, encouraging me, and supporting me to do the MMed degree in Anaesthesia.

Finally, last, but not least, I would like to thank my husband Mahlo, my daughter Modibone and my son Mohlapong for their unwavering support, trust, encouragement, and immeasurable sacrifice to allow me to devote all my family time for completing this project. Without them, this work would not have been possible and would have seemed worthless.

List of Abbreviations

ABG	Arterial blood gas
ACR	American College of Radiology
ARDS	Adult respiratory distress syndrome
CABG	Coronary artery bypasses grafting
CI	Confidence interval
CPB	Cardiopulmonary bypass
CT	Computed Tomography
CVP	Central venous pressure
CXR	Chest X-ray
ETT	Endotracheal tube
HIV	Human immunodeficiency virus
ICD	Intercostal drain
ICU	Intensive care unit
IVC	Inferior vena cava
LIMA	Left internal mamary artery
NAD	No abnormality detected
NGT	Nasogastric tube
PPC	Postoperative pulmonary complications
PPD	Postoperative pulmonary dysfunction
PTB	Pulmonary tuberculosis
SVC	Superior vena cava
VATS	Video-assisted thoracoscopic surgery

Abstract

Objective

Routine postoperative chest radiography after cardiac surgery is a common practice, although studies, both prospective and retrospective, conducted in their majority outside Africa, have shown that these chest radiographs are of low clinical value, mainly due to limited impact on patient management.

Following cardiac surgery and admission to ICU, chest radiographs are obtained in order to ensure proper position of all invasive devices such as endotracheal tubes, invasive catheters as well as nasogastric tubes, and to exclude possibility of a pneumothorax, atelectasis, infiltrates, and other potential respiratory complications associated with ventilatory support. Following cardiac surgery, there are other elements that require assessment: mediastinum (for widening due to bleeding), pleural space (for presence of fluid or air) and cardiovascular system (for presence of signs of failure). Specific to cardiac surgery is the post-operative pulmonary dysfunction (PPD), where systemic inflammatory response due to cardiopulmonary bypass is the main culprit [Milot J et al, 2001] – leading to acute lung injury.

Over and above the usual cardiovascular diseases that require surgical intervention, in Sub-Saharan Africa, inflammatory and infective conditions such as pulmonary tuberculosis, pulmonary hydatid disease, and pulmonary complications of HIV infection, are very prevalent. These pre-existing lung pathologies predispose patients to postoperative pulmonary complications after cardiac surgery. This audit investigates the role and importance of bedside chest X-rays in post operative care of cardiac surgery patients that come from a population group where lung pathology is quite prevalent.

Methods

302 medical records of patients that had undergone cardiac surgery between 1st September 2013 and 31st August 2014 were retrospectively analysed. The majority of the participants had heart valve replacements (45.6 %), CABG (35 %) or combination of these (7.6 %). Other procedures included: minimally invasive cardiac surgery (5.96 %), urgent surgery (9.2 %) and heart transplants (0.99%). Our diagnostic radiology consultant examined and reported on all chest radiological images that had been performed during the first 24hour period of the patient's stay in the Intensive Care Unit.

The role and importance of chest radiography in the post operative care of cardiac surgery patients was assessed by looking at therapeutic interventions prompted by the abnormal findings on the chest X-rays.

Results

Of the 577 chest radiographs performed on 302 patients (1.6 per patient), 222 (38.47%) had significant pathologic findings, but only 42 (7.28 %) chest radiographs led to therapeutic interventions. In the 17 post-PTB patients (5.63 % of the participants) only 1 chest X-ray had significant radiological findings - nevertheless, no intervention was carried out.

Conclusions

From the results of our study we conclude that chest radiography in post-cardiac surgery patients still has a role to play. Physical assessment alone has limitations in predicting abnormalities - these abnormalities (some can be life-threatening) can only be detected effectively and efficiently by chest radiography.

CHAPTER ONE

Introduction

Anaesthesia is a relatively new medical specialty in the vast array of specialities of medicine. New as it is - almost 170 years old – anaesthesia facilitated performance and development of surgery.

Anaesthesia for cardiac surgery is the most innovative and most challenging of all the branches within anaesthesia and its progress and development is inexorably intertwined with that of the ambitious, dynamic and constantly evolving cardiac surgery.

Anaesthesia in Groote Schuur Hospital was put on the map of the scientific world when... “The first human-to-human heart transplant was performed by a team led by Christiaan Barnard in Cape Town, South Africa, on December 3, 1967. The event, performed at the geographically isolated tip of Africa, stunned the world” [Gordon PC and Brink JG, 2008].

Out of the limelight of the big headlines and sensational photographs in the newspapers there is a long trail of hard work, scattered with sleepless nights, and soul-destroying doubts that plagued the lives of many great men and women. They made their contribution, significant or sometimes less significant, in the attempt to bring the science of anaesthesia to where it is today. From the discovery of ether and chloroform and endotracheal intubation to the elucidation of the molecular basis of action of various anaesthetic agents and their effects on ischaemic preconditioning of the myocardium, from the successful use of cardiopulmonary bypass machine in humans and the use of transoesophageal echocardiography to the performance of minimally invasive transcatheter aortic valve implantation, all these doctors worked continuously to discover, improve and perfect strategies and techniques to benefit more human beings.

This work carries on today at all levels of perioperative care: preoperatively, in an attempt to better stratify and improve risk; intraoperatively, where transoesophageal echocardiography use today illustrates best the successes in managing complex cardiac pathologies; as well as postoperatively, in ICU.

ICU is a complex, difficult, stressfull environment. This is where, following cardiac surgery, patients are brought in for further monitoring and support by various complicated invasive machines and devices. Life for these very sick patients would not be possible without continuous monitoring and support. Assessment of proper positioning and function, as well as detection of complications of these devices (endotracheal tubes (ETT) for mechanical ventilation, intercostal drains (ICDs) for surveillance, intra-aortic balloon pumps and central venous pressure catheters) have a significant impact on the overall care of ICU patients after cardiac surgery.

Following cardiac surgery, appropriate post-operative care of these critically ill patients relies on clinical evaluation which is assisted by imaging, and the chest X-ray is the most frequently requested imaging modality.

Bedside chest radiography is commonly performed in ICU: on admission, as a complement to physical examination, as well as after certain procedures. It is also performed if there are clinical indications, such as deterioration in the physical condition/haemodynamic status of the patient or alterations in the functioning parameters of the invasive machines or devices (increases in airway pressures or decreases in cardiac output).

Portable chest radiography is readily available, but comes at a cost, and has technical, diagnostic and safety limitations.

Care of patients in ICU is expensive. Various studies point out that it may be as high as 25-30% of a hospital's resources.

In view of the high incremental costs associated with portable chest X-rays, efforts to decrease utilization without placing the patient's safety at risk, could yield substantial savings.

Groote Schuur Hospital is one of the leading tertiary academic hospital in South Africa. It is also burdened (like all the other tertiary institutions) by financial constraints imposed by the rising costs of health care, and particularly ICU care. Nevertheless, it renders itself as an ideal environment to assess the impact/clinical value of routine portable post-operative chest X-rays in cardiac surgery patients in an attempt to reduce the costs, and as an opportunity to institute changes to the cardiac surgical care pathway of these critically ill patients.

Bibliography

1. Cohn LH, 2003, "*Fifty years of open-heart surgery*" *Circulation*, 107: 2168-2170
2. Gordon PC, and Brink JG, 2008, "*Forty years on: The anaesthetic for the world's first human-to-human heart transplant remembered*" *J Cardiothor Vasc Anesth*, 22 (1): 133-138.
3. Henschke CI, Yankelevitz DF, Wand A, Davis S, and Shiau M, 1997 "*Chest radiography in the ICU*" *Clinical Imaging*, 21: 90-103.
4. Hessel EA II, 2001, "*Cardiac anesthesia timeline*" *ASA Newsletter*, 65 (10).
5. Krinsley JS, 2003, "*Test-ordering strategy in the intensive care unit*" *J Intensive Care Med*, 18: 330-339.
6. Robinson DH, Toledo AH, 2012, "*Historical development of modern anesthesia*" *J Investigative Surgery*, 25: 141-149.
7. Trotman-Dickenson B, 2003, "*Radiology in the intensive care unit (part I)*" *J Intensive Care Med*, 18: 198-210.

CHAPTER TWO

Background

2.1. General information

Anaesthesia practitioners, as perioperative physicians, are ideally placed, by their training, understanding of physiology and pathophysiology, to bridge the continuum of care of critically ill patients from theatre, following surgery, to ICU.

The foundation of anaesthesia as a speciality has been vigilance and safety by means of monitoring of the patient while in need of support. This is achieved by frequent clinical examinations and supplementary investigations. Thus, the role of the anaesthetist has expanded beyond that of the perioperative physician to also include that of the critical care physician.

Aging of the South African population has resulted in a significant growth in the demand for both cardiac surgery as well as other surgical services. Cardiac surgery speciality, although under pressure from increasing numbers of patients, has spearheaded surgical innovations achieving remarkable results in a relatively short time period.

Substantial technological advances have been implemented to improve results while also decreasing the amount of surgical trauma associated with cardiac surgery (minimally invasive/minimal access cardiac surgery). New techniques are being applied in the treatment of coronary, valvular and aortic diseases, in the management of arrhythmia, and end stage heart failure.

The introduction of these new techniques has seen cardiothoracic surgeons operating on much younger, as well as much older patients, and on patients with more complex cardiac pathologies and increasingly more advanced associated co-morbidities. Technical ability to support these

very sick, critically ill patients through intricate, extensive surgery, places increasing demands on health care facilities, particularly intensive care units.

2.2. Complications following cardiac surgery

Cardiac surgery is high-risk surgery and when performed, as is usually the case, on patients with multiple associated conditions, the morbidity and mortality encountered add to the overall risks of these procedures. In the face of elevated figures related to mortality (anything between 1 - 3, and up to 5%) there are attempts to reduce these figures and improve, in a cost-efficient manner, the outcomes.

The postoperative period has been identified as one of the key areas where efficient monitoring and prompt, timely management of potential complications can prevent untoward mortality and morbidity and, as a result, reduce costs.

After undergoing cardiac surgery, most patients usually follow a fairly predictable postoperative course: the haemodynamic sequelae of surgery and cardiopulmonary bypass (CPB) abate and after 24-48 hours of uneventful ventilation, these patients can be extubated and discharged from the ICU.

Complications following cardiac surgery can be numerous, and vary in severity and aetiology. Leaving aside the bleeding and the haemodynamic instability most commonly due to surgical technique, pathophysiology of the underlying disease process, and/or coagulation management, the postoperative pulmonary dysfunction is a difficult to quantify and correct entity.

Pulmonary dysfunction, an ubiquitous consequence of cardiac surgery, particularly with cardiopulmonary bypass, has been identified as a

common source of complications in the postoperative period. It is the main reason, although not the only one, for the need for chest imaging.

The physiological changes that take place during cardio-thoracic surgery and lasting up to 8 weeks postoperatively [Johnson D et al, 1996], predispose patients to pleural, parenchymal and interstitial lung complications. Even after uncomplicated open heart surgery, a midline sternotomy, with or without rib retractions, causes significant reductions in lung volumes and lung capacities. These changes in lung mechanics will lead to abnormalities in gas exchange and may result in post-operative atelectasis, and, frequently quite significant hypoxaemia. Furthermore, cardiac surgery through its use of cardiopulmonary bypass produces a whole body inflammatory response that has been implicated, in its most severe form, in the production of acute respiratory distress syndrome [Asimakopoulos GP et al, 1999; Ng CSH et al, 2002; Andrejaitienne J et al, 2004; Peng MJ et al, 1992; Wiener-Kronish JP, 1992; Vargas FS et al, 1992; Huffmyer JL et al, 2015].

Post-operative pulmonary dysfunction (PPD), poorly defined and not well recognised, has a complex pathophysiology. Many elements are attributed to the aetiology of impaired pulmonary function after open heart surgery such as surgical technique, use of the internal mammary artery, anaesthetic technique/drugs, hypothermia, blood transfusion and extracorporeal circulation. The importance of this post-operative pulmonary dysfunction resides in the fact that 25-50% of those that do not present with haemodynamic/cardiovascular instability following heart surgery, will have marked pulmonary dysfunction for at least seven days after surgery [Apostolakis E et al, 2010; Wynne R et al, 2004; Ranier VM et al, 2012; Stephens RS et al, 2013; Weissman C, 2004; Vezzani A et al, 2014; Oks M et al, 2014; Henschke CI, 1983; Garcia-Delgado M et al, 2014].

It follows that post-operative pulmonary dysfunction is a significant clinical problem. It can manifest clinically as:

- pleural effusions (27-95 %);
- atelectasis (16-88%);
- phrenic nerve dysfunction (30-75%);
- pneumonia (4-20%); and
- ARDS (0.5-2%).

Acute respiratory distress syndrome (ARDS) as described by the recently published 2012 Berlin Definition of ARDS [Ranier VM et al, 2012], is a syndrome of acute hypoxaemic respiratory failure that occurs within one week of a known clinical insult, associated with bilateral opacities on chest imaging that cannot be explained by pleural effusion, atelectasis, nodules, cardiac failure or fluid overload.

“Cardiac surgery is a known risk factor for acute respiratory distress syndrome” [Milot J et al, 2001] and the more recent papers indicate that the incidence of this syndrome following cardiac surgery is 20% (much more than the previously described 0.5-2%) and the mortality is up to 80% (as opposed to 40% in the general population) [Stephens RS et al, 2013].

Further more, patients undergoing open heart surgery often have multiple comorbidities such as pleural, interstitial and/or parenchymal lung disease, or, as is more commonly the case in South Africa, pulmonary tuberculosis. These patients can also have respiratory impairment as a result of cardiac dysfunction, like congestive heart failure, thus increasing their susceptibility to postoperative respiratory complications [Weissman C, 2004].

Add to all these the potential complications associated with intubation and mechanical ventilation in the ICU, such as: inadvertent extubation, endobronchial intubation, pneumothorax, lobar collapse due to mucous/blood clot, inappropriate positioning of tubes and invasive lines, accumulation of air, fluid, or blood in the pleura, pericardium or interstitial space. Some of these complications can have immediate dire consequences if unrecognised and if their management is delayed.

2.3. Diagnosis of potential complications

Following cardiac surgery, these critically ill patients have a labile, easily disturbed physiology and will require continuous monitoring. Very often, they will remain intubated following their surgery, to be further ventilated, and most of the times, will require haemodynamic support: either pharmacological (inotropes by means of central lines), and/or mechanical support (intra-aortic balloon pump).

Everything can go wrong at any stage, hence, the continuous monitoring to allow timeous intervention should that be needed - like in the development of life-threatening complications.

The diagnosis of these complications can be made by:

- clinical examination;
- radiological imaging (chest radiography, chest ultrasonography);
- arterial blood gas analysis;
- waveform analysis of invasive supportive machines and devices (ventilators, balloon pump, cardiac output monitor, invasive catheters).

Clinical examination, readily performed, at any stage, by any doctor, in the set up of critically ill patient in ICU may prove to be difficult to perform, not in the least due to poor access to the patient – open chest, dressings, monitors, invasive devices, chest drains, infusion pumps – to mention just a couple of existing barriers.

Auscultation, which is the first step of the clinical evaluation of the respiratory system, can be markedly influenced by the intrathoracic transmission of sounds from the mechanical ventilation [Lichtenstein DA et al, 2005], as well as by the noisy environment.

Pneumothorax, for example, although an easily defined entity, may not be clinically evident unless it causes substantial haemodynamic and/or

respiratory compromise [Rowan KR et al, 2002]. The subtle reduction or even complete abolition in breath sounds may not be detected by auscultation. Depending on its size, a small pneumothorax can be reabsorbed within a couple of days, or, if massive, can lead to life-threatening tensioning and cardiovascular collapse.

Radiological imaging such as radiography, computed tomography, angiography, ultrasonography, an important aid in elucidating both expected and unsuspected pathological abnormalities, has moved from diagnosis to therapeutics thus increasing the contribution of image-guided interventional procedures to patients' management in ICU.

“Chest radiography is the oldest, most common and least sophisticated” [Henschke CI et al, 1997] of the radiological imaging techniques. It is not the only one! There are others, more advanced imaging modalities, such as computed tomography, chest ultrasound, echocardiography.

Ultrasound is a low cost non-ionizing energy source and is considered to be safe. The equipment is portable and can easily be used for bedside imaging. The need for a trained, experienced operator and the poor visualization of structures underlying bone or air can raise a number of issues. Scattering of sound waves through fat yields poor images in obese patients – not a minor consideration in view of the obesity epidemic. Recent studies have advocated chest ultrasound imaging as a valid alternative to chest radiography in an attempt to detect postoperative abnormalities and misplacements of invasive devices and to reduce the number of alternative radiological investigations [Vezzani A et al, 2014; Oks M et al, 2014].

Computed tomography (CT) with its high ionizing radiation, produces cross-sectional images of specific areas by a combination of multiple X-ray images which are processed through a computer. Chest CT is known to have a good contrast resolution allowing better differentiation of tissues

with similar physical properties. This is an expensive radiological investigation and exposes patients to high ionizing radiation.

For this investigation (CT) patients have to be transferred out of ICU to CT scan suite - these very sick patients in most circumstances are dependent on the supporting technology (ventilators, aortic balloon pumps) and thus, become exposed to the hazards of transport along corridors to reach the remote sites of radiological suites.

Risk-benefit and cost analysis must become a very important, carefully considered exercise, before subjecting these patients to the whole process of transfer to have a CT scan.

Echocardiography, be it transthoracic or transoesophageal, has superseded most diagnostic modalities and revolutionized the perioperative management, particularly in the context of cardiac pathology/cardiac anaesthesia. It is also expensive, not only in terms of equipment, but also in terms of training requirements and certification in order to make full use of altering patients' management capabilities.

In spite of all these new imaging techniques the role of chest radiography has not been completely obliterated. Chest X-ray is still used as a first line imaging technique following the admission of patients to ICU and is often the only radiological examination performed on what is, probably, one of the most critically ill patient in the hospital [Henschke CI et al, 1983].

The information obtained from chest radiography forms the basis for management decisions in these critically ill patients.

Bedside chest radiography aids in the diagnosis and detection of occult complications, assessing position of monitoring and therapeutic devices, as well as helping to determine the presence of a pneumothorax, atelectasis, infiltrates, or other potential respiratory complications associated with ventilator support in the ICU. Chest X-ray is also useful in assessing the cardiovascular status of patients before clinical deterioration

becomes evident. Following surgical intervention, especially after sternotomy or thoracotomy there are other elements that require assessment: mediastinum (widening due to bleeding); pleural space (presence of fluid or air); appropriate positioning of supportive devices such as endotracheal and nasogastric tubes, intra-aortic balloon pump, pulmonary artery catheter, central venous catheters.

Although a primary tool for radiographic evaluation of the very sick patients, chest radiography has a number of limitations.

The quality of bedside chest radiography is reduced by technical problems with implications on interpretation, diagnosis and further management. These limitations include:

- the presence of machines, infusion pumps and other devices that limit access to the patient;
- dressings, chest drains and different invasive devices that may lead to a number of interpretation artefacts;
- difficulties with timing of the exposure to the deep-inspiration end and in the upright position;
- consistency in technique to be able to compare with a baseline X-ray [Weiss YG, 2000].

“All of these various factors contribute to poor quality of the X-ray films and mistaken assessment of pleural/pericardial effusions, alveolar consolidation/lobar collapse, artefactual interpretation of interstitial markings, as well as misinterpretation of the mediastinal and cardiac dimensions” [Lichtenstein DA et al, 2001].

Despite careful and good control of exposure factors, bedside chest radiography can result in poor and suboptimal radiographic images in more than one third of cases [Henschke CI et al, 1983].

Interpretation of the chest images can be extremely challenging. Superimposed anatomical structures make the image and the confluence

of lines and shadows complicated [Van Ginneken B et al, 2001]. Even experienced radiologists have difficulty distinguishing between normal lung tissue and infiltrates.

Returning to the example of the pneumothorax, “on an antero-posterior chest X-ray a pneumothorax may not be evident if it does not produce a deep sulcus sign. Also, the sharp delineation of the pericardial silhouette or the large asymmetric area of hyperlucency in one of the hemithoraces can be missed/not seen” [Rowan KR et al, 2002]. To increase the sensitivity of radiographs in depicting pneumothoraces, the image has to be obtained with the patient in an upright position. This does not really help: ICU patients cannot be positioned upright due to haemodynamic instability, sedation/pain issues, as well as the presence of various invasive devices that could be dislodged.

Technological advances in the field of imaging have enabled some progress. “Digital radiography with its Picture Archiving and Communication System (PACS) allows for consistent image quality over a much wider range of exposures” [Henschke CI et al 1997] as well as instant access of the processed images in the ICU. It also introduces tools that help identify pathologies, like zoom functions and edge enhancement [Hurlen P et al, 2012; Singh NP et al, 1992]. Consequently, optimization of image acquisition and quality is going to be reflected in sensitivity of the diagnostic efficacy and accuracy of the chest radiograph in the radiologically unfriendly and difficult ICU environment.

Arterial blood gas analysis is the method used to quantify the degree of hypoxaemia that follows cardiac surgery [Weiss YG, 2000; Veldkamp WJH et al, 2009]. Ubiquitous in the first 6 hours after surgery, hypoxaemia associated with cardiopulmonary bypass is too easily influenced (too many confounders) by multiple preoperative factors (like pre-existing lung disease and age) as well as multiple intraoperative variables (amount of fluids and blood transfused, surgical technique and time on bypass, anaesthetic technique and parameters of ventilation) to be a useful marker

for patients more likely to develop complications. Nevertheless, hypoxaemia is a constant companion to postoperative complications.

Waveform analysis of invasive supportive machines and devices, such as ventilators, arterial lines, central venous catheters lines, intra-aortic balloon pumps, although an interesting concept, and utilised in assessing mostly cardiac output and the use of inotropic agents, requires more investigation with respect to clinical value in diagnosing complications.

2.4. The need to investigate the investigations

The spiralling costs of health, health maintenance, health prevention, and health care have led to an augmentation in the interest of determining the factors/methods that can reduce these costs in an efficient and effective manner, while, at the same time preserving patient safety.

Care of the patients in ICU following cardiac surgery is expensive – in some studies shown to represent 25-30% of a hospital's resources. Although personnel compensation probably accounts for a great part, the costs associated with laboratory and diagnostic services are considerable [Veldkamp WJH et al, 2009].

It is quite remarkable that a patient population of approximately 7–12 % uses more than a third (30%) of all the portable chest radiographs in a hospital [Krinsley JS, 2003; Henschke CI et al, 1997].

The figures/percentages for the South African setting might be even more daunting to consider given the socio-economic situation of our country [Bhagwanjee S and Scribante J, 2007].

Observations that various forms of testing (radiology included) are often of minimal value suggest all such “routine” tests should be justified by careful assessment.

Because of our position in the entire continuum of perioperative care, including post-operative ICU care, and as a result of our understanding of physiology and the effects that disease and surgery can have on physiology, we, as anaesthetists, have been afforded an opportunity to influence many of the practices that can be associated with both poor outcomes and increased costs.

Routine post-operative chest radiography following cardiac surgery has become a standard of care in a number of cardiothoracic ICUs.

Nevertheless “the value of the immediate postoperative chest radiograph upon a patient’s return to the intensive care unit after a cardiac surgical procedure is uncertain” [Hornick PI et al, 1995] and has been questioned.

Spiralling costs of health care and the need for evidence-based medicine and cost-effective practices, have challenged the routine protocol-driven chest radiography [Eisenberg RL et al, 2001] in both medical and surgical the intensive care units.

Over the last 30-40 years many studies, mostly prospective, have looked at the role and importance of routine chest radiography in ICUs, and the general consensus reached is that routine chest radiographs do not play a major role in the management of ICU patients [O’Brien W et al, 1997; Krivopal M et al, 2003; Mets O et al, 2007; Hejblum G et al, 2009; Oba Y and Zaza T, 2010; Tolsma M et al, 2011; Lakhal K et al, 2012; Ganapathy A et al, 2012].

Very few studies looked specifically at the patients that underwent cardiac surgery.

Some of these researchers are very cautious about completely abandoning such a practice (routine chest X-rays) [Oba Z and Zaza T, 2010; Ganapathy A, 2012].

All of the studies that have advocated abandoning of the routine chest X-rays following cardiac surgery have been conducted outside Africa [Hornick PI et al, 1995; O'Brien W et al, 1997].

The only study done in Africa [Bhagwanjee S and Muckart DJJ, 1996] indicated that “clinical examination can effectively predict the need for radiography” and recommended abandoning routine chest X-ray in young adult patients that are mechanically ventilated in a surgical ICU. It also cautioned that “units should consider investigating the value of this practice” before the discontinuation of routine chest radiography is adopted.

In Sub-Saharan Africa, in addition to the usual cardiovascular diseases that require surgical intervention, inflammatory and infective conditions such as pulmonary tuberculosis, pulmonary hydatid disease, as well as pulmonary conditions associated with human immunodeficiency virus (HIV) infection, are prevalent.

Pre-existing lung pathology has been implicated in the development of post-operative pulmonary complications.

This audit was then undertaken to retrospectively investigate the impact of chest X-rays following cardiac surgery in the management of a population group in which lung pathology is assumed to be prevalent. No other study has investigated the clinical value of chest X-ray following cardiac surgery in a population that has a high incidence of pre-existing lung disease.

Bibliography

1. Andrejaitiene J, Sirvinskas E, Bolys R, 2004, "*The influence of cardiopulmonary bypass on respiratory dysfunction in early postoperative period*" *Medicina*, 40 (1): 7-12.
2. Apostolakis E, Filos KS, Koletsis E, Dougenis D, 2010, "*Lung dysfunction following cardiopulmonary bypass*" *J Card Surg*, 25: 47-55.
3. Asimakopoulos GP, Smith PLC, Ratnatunga CP, Taylor KM, 1999, "*Lung injury and acute respiratory distress syndrome after cardiopulmonary bypass*" *Ann Thorac Surg*, 68: 1107-1115.
4. Bhagwanjee S, Scribante J, 2007, "*National audit of critical care resources in South Africa – unit and bed distribution*" *S Afr Med J*, 97 (12): 1311-1314.
5. Bhagwanjee S, Muckart DJJ, 1996 "*Routine daily chest radiography is not indicated for ventilated patients in a surgical ICU*" *Intensive Care Med*, 22: 1335-1338.
6. Eisenberg RL, Khabbaz KR, 2001, "*Are chest radiographs routinely indicated after chest tube removal following cardiac surgery?*" *Am J Roentgenol*, 197: 122-124.
7. Ganapathy A, Adhikari NKJ, Spiegelman J, Scales DC, 2012, "*Routine chest x-rays in intensive care units: a systematic review and meta-analysis*" *Critical Care*, 16 (2): R68.
8. Garcia-Delgado M, Navarrete-Sanchez I, Colmenero M, 2014, "*Preventing and managing perioperative pulmonary complications following cardiac surgery*" *Curr Opin Anesthesiol*, 27 (2): 146-152.
9. Grocott HP, Stafford-Smith M, Mora-Mangano CT, 2011, Chapter 28: Cardiopulmonary bypass management and organ protection in *Kaplan's Cardiac Anesthesia: The Echo Era*, 6th Ed, 838-887.
10. Hejblum GI, Chalumneau-Lemoine L, loos V, Boelle P, 2009, "*Comparison of routine and on-demand prescription of chest radiographs in mechanically ventilated adults: a multicentre, cluster randomised, two-period crossover study*" *Lancet*, 374: 1687-1693.

11. Henschke CI, Pasternack GS, Schroeder S, Hart KK, Herma PG, 1983, "*Bedside chest radiography: diagnostic efficacy*" Radiology, 149:23-26.
12. Henschke CI, Yankelevitz DF, Wand A, Davis S, Shiau M, 1997, "*Chest radiography in the ICU*" Clinical Imaging, 21: 90-103.
13. Hornick PI, Harris P, Cousins C, Taylor KM, Keogh BE, 1995, "*Assessment of the value of the immediate postoperative chest radiograph after cardiac operation*" Ann Thorac Surg, 59: 1150-1154.
14. Hurlen P, Borthne A, Dahl FA, Ostbye T, Gulbrandsen P, 2012, "*Does PACS improve diagnostic accuracy in chest radiograph interpretations in clinical practice?*" Eur J Radiology, 81: 173-177.
15. Huffmyer JL, Groves DS, 2015, "*Pulmonary complications of cardiopulmonary bypass*" Best Pract & Res Clin Anaesthesiol, 29: 163-175.
16. Johnson D, Hurst T, Thomson D, 1996, "*Respiratory function after cardiac surgery*" J Cardiothor Vasc Anesth, 10(5): 571-577.
17. Krinsley JS, 2003, "*Test ordering strategy in the intensive care unit*" J Intensive Care Med, 18: 330-339.
18. Kripostal M, Shlobin OA, Schwartzstein RM, 2003, "*Utility of daily routine portable chest radiographs in mechanically ventilated patients in the medical ICU*" Chest, 123 (5): 1607-1614.
19. Lakhal K, Serveaux-Delous M, Lefrant JY, Capdevilla X, Jaber S, 2012, "*Chest radiographs in 104 French ICUs: current prescription strategies and clinical value (the RadioDay study)*" Intensive Care Med, 38: 1787-1799.
20. Lichtenstein DA, Meziere G, Lascols N, Bideman P, Courret J-P, Gepner A, Goldstein I, Tenoudji-Cohen M., 2005, "*Ultrasound diagnosis of occult pneumothorax*" Crit Care Med, 33 (6): 1231-1238.

21. Mets O, Spronk PE, Binnekade J, Stoker J, 2007, *“Elimination of daily routine chest radiographs does not change on-demand radiography practice in post-cardiothoracic surgery patients”* J Thorac Cardiovasc Surg, 134 (1): 139-144.
22. Milot J, Perron J, Lacasse Y, Le'tourneau L, Cartier PC, Maltais F, 2001, *“Incidence and predictors of ARDS after cardiac surgery”* Chest, 119: 884-888.
23. Nussmeier NA, Sarwar MF, Searles BE, 2015 *“Chapter 67: Anesthesia for cardiac surgical procedures”* in Miller's Anesthesia, 8th ed, 2007-2095.
24. Ng CSH, Wan S, Yim APC, Arifi AA, 2002, *“Pulmonary dysfunction after cardiac surgery”* Chest, 121 (4): 1269-1277.
25. Oba Y, Zaza T, 2010, *“Abandoning daily routine chest radiography in the intensive care unit: meta-analysis”* Radiology, 255 (2): 386-395.
26. O'Brien W, Karski JM, Cheng D, Carrol-Munro J, Penston C, Sandler A, 1997, *Routine roentgenography on admission to intensive care unit after heart operations: is it of any value?* Journal Thoracic Cardiovasc Surg, 113: 130-133.
27. Oks M, Cleven KL, Cardenas-Garcia J, Schaub JA, Koenig S, Cohen RI, Mayo PH, 2014, *“The effect of point of care ultrasonography on imaging studies in the medical ICU”* Chest, 146 (6): 1574-1577.
28. Peng MJ, Vargas FS, Cukier A, Terra-Filho M, Teixeira LR, Light RW, 1992, *“Postoperative pleural changes after coronary revascularization: comparison between saphenous vein and internal mammary artery grafting”* Chest, 101 (2): 327-330.
29. Ranieri VM, Rubenfeld GD, Thompson BT, Ferguson ND, 2012, *“Acute respiratory distress syndrome: the Berlin definition”* JAMA, 307(23): 2526-2533.
30. Rowan KR, Kirkpatrick AW, Liu D, Forkheim KE, Mayo JR, Nicolaou S, 2002, *“Traumatic pneumothorax detection with*

- thoracic US: correlation with chest radiography and CT – initial experience*” *Radiology*, 225 (1): 210-214.
31. Singh P, Vargas FS, Cukier A, Terra-Filho M, Teixeira LR, Light RW, 1992, “*Arterial blood gases after coronary artery bypass surgery*” *Chest*, 102 (5): 1337-1341.
 32. Skubas NJ, Lichtman AD, Sharma A, Thomas SJ, 2013, “*Chapter 38: Anesthesia for cardiac surgery*” in *Barash’s Clinical Anesthesia*, 7th Ed, 1076-1111.
 33. Stephens RS, Shah AS, and Whitman GJG, 2013, “*Lung injury and acute respiratory distress syndrome after cardiac surgery*” *Ann Thorac Surg*, 95: 1122-1129.
 34. Tolsma M, Kroner A, van den Hombergh CLM, Rosseel P, Rijpstra T, Dijkstra HA, 2011, “*The clinical value of routine chest radiographs in the first 24 hours after cardiac surgery*” *Anesth Analg*, 112 (1): 139-142.
 35. Van Ginneken B, Ter Haar Romeny BM, Viergever MA, 2001, “*Computer-aided diagnosis in chest radiography: a survey*” *IEEE Trans Med Imag*, 20 (12): 1228-1241.
 36. Vargas FS, Cukier A, Terra-Filho M, Hueb W, Teixeira LR, Light RW, 1992, “*Relationship between pleural changes after myocardial revascularization and pulmonary mechanics*” *Chest*, 102 (5): 1333-1336.
 37. Veldkamp WJH, Kroft LJM, and Geleijns J, 2009, “*Dose and perceived image quality in chest radiography*” *Eur J Radiology*, 72: 209-217.
 38. Vezzani A, Manca T, Brusasco C, Santori G, Valentino M, Nicolini F, Morladi A, Gherli T, Corradi F, 2014, “*Diagnostic value of chest ultrasound after cardiac surgery: a comparison with chest X-ray and auscultation*” *J Cardioth Vasc Anaesth*, 28(6): 1527-1532.
 39. Weiss YG, Merin G, Koganov E, Ribo A, Oppenheim-Eden A, Medalion B, Peruanski M, Reider E, Bar-Ziv J, Hanson WC,

- Pizov R, 2000, *“Postcardiopulmonary bypass hypoxemia: a prospective study on incidence, risk factors, and clinical significance”* J Cardiothor Vasc Anesth, 14(5): 506-513.
40. Weissman C, 2004, *“Pulmonary complications after cardiac surgery”* Sem Cardiothor Vasc Anesth, 8 (3): 185-211.
41. Wiener-Kronish JP, 1992, *“Postoperative pleural and pulmonary abnormalities in patients undergoing coronary artery bypass grafting”* Chest, 102 (5): 1313-1314.
42. Wynne R, and Botti M, 2004, *“Postoperative pulmonary dysfunction in adults after cardiac surgery with cardiopulmonary bypass: clinical significance and implications for practice”* Am J Crit Care, 13: 384-393.

CHAPTER THREE

Review of Literature

3.1. Objectives of literature review

The main objectives of this literature review are to examine and analyse the current published literature on the role and importance of routine chest X-ray following cardiac surgery and to evaluate, based on this, the ability to change practice in the way critically ill patients are cared for. Although there are a number of studies that have investigated the role of routine chest radiograph in the care of patients in ICU, there is limited published literature regarding the value of chest radiograph in the post-cardiac surgery patient population.

The second objective is to identify methods used in previous studies to determine the diagnostic and therapeutic efficacy of the chest radiograph.

3.2. Literature search strategy

A PubMed literature search was undertaken, and the following terms/phrases were used: bedside chest radiography; cardiac surgery; chest radiograph; daily chest X-ray; diagnostic efficacy; intensive care unit; postoperative chest X-ray; routine vs on-demand chest radiography; therapeutic efficacy.

Bibliographies from specific articles obtained from the PubMed search were reviewed and the additional relevant papers were included in the review of literature.

To guide the search and gain insight from various points of view with respect to the importance of chest radiograph in the post operative period

interviews were conducted with doctors from various specialties: cardiothoracic surgeons, cardiac anaesthetists, as well as ICU physicians.

The University of Cape Town Health Science Library search facility, with access to 17 medical digital archive databases worldwide was used as a source for relevant scientific articles and publications. Literature published from 1980 and up to 2015 was included.

The following journals were included in the search:

- American Journal of Roentgenology;
- Anesthesia and Analgesia;
- Anesthesiology;
- Annals of Intensive Care;
- Annals of Thoracic Surgery;
- Best Practice & Research Clinical Anaesthesiology;
- British Journal of Anaesthesia;
- Chest;
- Clinical Imaging;
- Clinical Radiology;
- Critical Care;
- Critical Care Clinics;
- European Journal of Cardiothoracic Surgery;
- Intensive Care Medicine;
- Journal of Cardiothoracic and Vascular Anesthesia;
- Journal of Critical Care Medicine;
- Journal of Thoracic and Cardiovascular Surgery;
- Lancet;
- Radiology;
- Radiology Research and Practice.

The following reference books have provided guidance and direction in our search: - *Miller's Anesthesia*, 8th Ed, 2015; Chapter 67: Anesthesia for Cardiac Surgical Procedures, 2007-2095;

- *Barash's Clinical Anesthesia*, 7th Ed, 2013, Chapter 38: Anesthesia for Cardiac Surgery, 1076-1111; and

- *Kaplan's Cardiac Anesthesia: The Echo Era*, 6th Ed, 2011.

In addition, two websites have been visited: the website of the American College of Radiology for the *Appropriateness Criteria* (www.acr.org/ac) as well as the website of the Interactive Journal of Cardiothoracic Surgery (www.icvts.oxfordjournals.org).

In total, 49 scientific papers were identified and critically analysed.

Literature not published in the English language was excluded.

3.3. Summary and interpretation of the literature

Between 30 and 50% of all radiological examinations in the world are probably chest radiographs. Approximately 60% of these chest radiographs are ordered for routine examinations [Geijer M, et al, 2012; Geijer M, et al, 1998]. This represents substantial use of health care resources.

Given the frequent use of the chest X-ray with its respective costs and potential hazards due to radiation exposure (however small some consider it to be [Veldkamp WJH, et al, 2009]) the clinical importance of post operative chest X-ray has been questioned in numerous studies.

Some of the published studies report a low clinical value of routine chest radiograph in a variety of circumstances: admission [Verma V, et al, 2011; Malnick S, et al, 2010]; screening (for detection of cardiac disease, PTB, lung cancer) [Tape TG, et al, 1986; Robin ED, et al, 1986]; preoperatively [Archer C, et al, 1993]; and postoperatively [Barak M, et al, 1997]. All these studies report abnormal radiological findings on the chest radiograph that result in therapeutic intervention in only approximately 4% of patients. All these studies come to the conclusion

that to lessen the work burden and curtail costs, performance of chest radiography should be limited to a clinically based indication rather than routine ordering.

The ordering of routine chest X-rays after cardiac surgery is also a common worldwide practice despite the fact that the clinical value of these radiographs is known to be low [Stevens JJMW, et al, 1995; Hornick PI, et al, 1995; O'Brien W, et al, 1997; Rao PS, et al, 1997; Leong CS, et al, 2000; Karthlik S, et al, 2006; Mets O, et al, 2007; Tolsma M, et al, 2011; Tolsma M, et al, 2014; Tolsma M, et al, 2015].

There are two types of strategies that are employed in obtaining chest radiographs in the intensive care unit, namely: *routine chest radiograph* and *on-demand chest radiograph*.

Routine chest radiograph refers to the chest radiograph obtained as a standard procedure following admission to ICU to ensure proper positioning of endotracheal tube, nasogastric tube, appropriate location of invasive lines and catheters, as well as to determine the presence of a pneumothorax, atelectasis or other potential respiratory complications associated with ventilatory support. Following cardiac surgery there are other elements that require assessment: mediastinum (widening in case of bleeding); pleural space (presence of fluid or air); pericardium (fluid); appropriate positioning of the surveillance drains and supportive devices (intra-aortic balloon pump, ventricular assist devices).

Following removal of chest drains (pleural or pericardial) by cardiothoracic surgeons, routine chest radiograph is, again, common practice.

In unintubated patients, routine chest X-ray is obtained in ICU following intubation – to assess appropriate placement of the endotracheal tube.

Following insertion of a central venous catheter or of a pulmonary artery catheter, chest X-ray is also obtained routinely.

Support devices like intra-aortic balloon pump and cardiac assist devices are also susceptible to numerous serious complications, particularly related to their malpositioning. A routine (following insertion) chest radiograph can help identify incorrect placement and can direct initiation of appropriate management [Trotman-Dickenson B, et al, 2003; Baskett RFJ, et al, 2002].

Obtaining routine chest X-rays has the following advantages [Ganapathy A, et al, 2012]:

- Prompt discovery and earlier treatment of otherwise unsuspected abnormalities;
- Documentation of appropriate positioning of tubes, lines and supporting devices;
- Documentation of progression of disease, response to therapy; and
- Education/teaching value for trainees.

Potential disadvantages to routine prescription/performance of chest radiographs include:

- Low yield of clinically unsuspected abnormalities;
- Potential harm to the patient with the execution of the chest X-ray (discomfort, pain, unintentional displacement of catheters, tubes, lines, supporting devices [loos V, et al, 2011]) and that resulting from treatment of minor findings;
- Cost; and
- Radiation exposure.

On-demand chest radiograph refers to the chest radiograph ordered/prescribed after a modification in the clinical condition of the patient, such as unexplained desaturation, haemodynamic instability, and development of a fever - the chest X-ray is used to locate the source of infection or to determine a change of invasive supportive device.

Obtaining chest X-rays on an on-demand instead of on a routine basis may have the following advantages [Oba Y and Zaza T, 2010]:

- Unnecessary radiation exposure to patients and healthcare personnel is avoided;
- The unfavourable outcomes associated with patient positioning and moving for the performance of the chest radiograph (discomfort, pain, displacement of tubes, invasive devices and the complications thereof) are minimised/reduced; and
- There are substantial health care cost savings with reduced workload.

Potential disadvantages of performing an on-demand chest X-rays are:

- Important abnormalities may be missed by the restriction of chest X-rays with delays in instituting therapy and prolongation of ICU stay with, therefore, potential increases in morbidity and mortality;
- Potential increase in after-hours chest X-rays requirements and/or an increase in alternative thoracic imaging (CT chest or chest ultrasound) with its associated increase in workload in a vulnerable time period.

Over the years, the clinical value of routine chest radiography in patients in ICU, particularly those that are mechanically ventilated has become a bone of contention amongst anaesthetists and intensivists.

Doctors oscillated from the initial hesitancy to use “the roentgen ray” because of “its inaccuracy and the dangers attending to its use” to “acceptance and widespread use not based on scientific fact but on the basis of the faith that technology would aid in the care of patients” [Gurney JW, 1995].

The substantial benefits associated with routine chest X-ray performance are marred by related significant economic and clinical costs [Price MB, et al, 1999; Graat ME, et al, 2007].

The increasing health care costs (especially in ICUs) and the potential hazards of radiation exposure have led to the examination of tests, including radiography, that may be omitted from patient care [Bekemeyer WB, et al, 1985].

Questions regarding the efficacy of diagnostic radiography in varied clinical situations [Bekemeyer WB, et al, 1985] were the seed of today's Appropriateness Criteria of the American College of Radiology (ACR). They originated at a time when "the practice of providing the best care technically possible, regardless of cost" [Loop JW and Lusted LB, 1978] were just about to start being challenged.

Diagnostic efficacy, as defined by the ACR, is the number of radiographs with a new or progressive significant/major finding divided by the total number of radiographs. It is an indicator of the value of the chest X-ray in assisting in diagnosis [Kager LM, et al, 2010].

Therapeutic (management) efficacy is the number of chest X-rays resulting in a change in clinical management divided by the total number of chest X-rays. There are other factors that intervene in the clinical decision-making process, including radiographic evidence of no change – underlying the multifaceted aspect of clinical management. Therapeutic efficacy is an indicator of the influence of the radiograph on the patients' clinical management [Hendrikse KA, et al, 2007; Henschke CI, et al, 1983; Hall JB, et al, 1991].

Outcome efficacy is the ultimate impact of the test and its results/effects on patient morbidity and mortality. It is a much more difficult contribution to evaluate and assess, although more recent studies (mostly prospective) have attempted this [Mets O, et al, 2007; Tolsma M, et al, 2011; Ganapathy A, et al, 2012; loos V, et al, 2011; Krivopal M, et al, 2003; Hejblum G, et al, 2009].

The American College of Radiology (ACR) Appropriateness Criteria [Suh RD, et al, 2014] (last reviewed in 2014) on routine chest radiography in ICU patients recommend the following:

- An initial ICU admission radiograph for patients admitted for cardiac monitoring, or in stable patients admitted for extra-thoracic disease, with follow-up radiographs only for specific clinical indications including clinical worsening and tube or line insertion;
- Radiographs are indicated following initial placement of an endotracheal tube, central venous catheter, pulmonary artery catheter, nasogastric tube, chest drain, or any other life-support item;
- Change in the clinical condition of the patient is an indication for a chest radiograph;
- Routine daily chest radiograph for patients in ICU is not indicated.

Data from the 1980s and early 1990s showed a high incidence (37 - 65%) of new or unexpected findings on chest X-rays that supported the use of daily chest radiographs in these patients [Henschke CI, et al, 1983; Hall JB, et al, 1991]. These earlier studies do not detail the ways in which the abnormal, new, or unexpected findings, helped to formulate the diagnosis or changed management.

It is these studies that form the basis for the ACR Appropriateness Criteria recommendations for routine chest X-ray following admission to ICU.

More recent studies [Ganapathy A, et al, 2012; Oba Y and Zaza T, 2010] have documented a lower incidence of unexpected abnormalities on the radiographic images and as a result have advised abandoning the practice of routine chest radiograph.

There are numerous studies [Bekemeyer WB, et al, 1985; Owen RL and Cheney FW, 1987] documenting the utility of post-intubation chest radiographs in assessing the position of the endotracheal tube, but not the efficacy of radiographs obtained daily, on a routine basis.

The studies that compared the radiographs to the clinical examination in determining the malpositioning of the endotracheal tube found that clinical examination (auscultation and ballotment of the endotracheal cuff in the suprasternal notch) is not accurate. Chest X-rays immediately postintubation are important in ensuring appropriate placement of the endotracheal tube.

Other studies document the utility of chest radiographs following the insertion of a central venous pressure catheter for the detection of potential complications resulting from malpositioning. These studies also describe the features (multiple needle passes, operator experience, poor anatomical landmarks, site attempted, previous CVP line placements [Gray P, et al, 1992; Gladwin MT, et al, 1999] most likely associated with malpositioning resulting in complications – potentially assisting in defining the indications for selective/restrictive chest radiography after central venous catheterization. While the follow-up chest X-rays after the initial insertion of the CVP line, have a low yield for detecting complications, a chest radiograph immediately after the insertion seems (for now) necessary to illustrate proper positioning.

A commonly performed procedure in the ICU is insertion of chest drains and, in due time, removal of these drains. While chest radiography is agreed upon and routinely performed following insertion of the chest tube, it is the post-removal chest radiograph that has been questioned with respect to clinical utility. Studies [Palesty JA, et al, 2000; Khan T, et al, 2008; Whitehouse MR, et al, 2009; Eisenberg RL, et al, 2011; Sepehripour AH, et al, 2012] investigating particularly the efficacy of the chest X-ray after chest tube removal in surgical cardiothoracic patients have come to the conclusion that “chest radiography following removal of chest tubes should not be a routinely performed procedure, but should preferably be based on the good clinical judgement and discrimination of the surgeon” [Palesty JA, et al, 2000].

There are numerous studies investigating the role and importance of the routine chest radiograph in the intensive care unit. These studies are quite heterogenous with respect to:

- the type of patient population studied (paediatric, adult; medical, surgical; general surgical, cardiothoracic surgical; mechanically ventilated, nonventilated);
- the sample size of patients studied (from a couple of tens of patients to a couple of hundreds of patients studied);
- the type of studies (prospective, retrospective; observational, interventional; single centre, multicentre);
- the type of ICU where the frequency of chest X-rays was investigated (medical, surgical, mixed: medical-surgical);
- the reasons for the prescription of the chest radiograph (following admission to ICU, following a procedure: intubation, central vein cannulation, insertion/removal of chest drains);
- what constitutes “routine” and what constitutes “on-demand” ordering strategy;
- the time frame during which the investigation took place (a couple of hours: 24-48 hours to a good couple of weeks following the surgical intervention);
- the outcomes investigated (rates of new findings on X-rays, rates of new findings that prompted therapeutic interventions, rates of delayed diagnoses, ICU mortality, ICU length of stay, duration of mechanical ventilation, bedside radiography use, and total length of hospital stay).

Despite all these inconsistencies, there is considerable consensus regarding the appropriate role of chest radiography in the intensive care unit [Henschke CI, et al, 1997] and that is well reflected in the recommendations of the ACR Appropriateness Criteria [Suh RD, et al, 2014].

It is the effect on outcome that has the most impact on the way medicine is being practiced today. Yet outcome is an elusive entity. It can mean many things to different people in different circumstances, particularly along the windy road of clinical decision making. Under the circumstances of scarce resources, decision makers must consider the important contributions of an intervention towards health care in relation to its costs, with an understanding of what is a “favourably influenced” outcome. Also to be taken into account is the fact that there is a long thread connecting the chest radiograph as an imaging diagnostic tool to the ultimate goal which is to improve outcome - patient’s health, life expectancy, quality of life - at a reasonable cost [Elshaug AG, et al, 2010].

From a scientific point of view, proof of outcome efficacy of a test [Fryback DG, et al, 1991] requires a prospective randomized controlled trial of withholding the test from some patients. This is what the authors of more recent studies [Mets O, et al, 2007; Tolsma M, et al, 2011; Ganapathy A, et al, 2012; loos V, et al, 2011; Krivopal M, et al, 2003; Hejblum G, et al, 2009] that investigated various outcomes (number of chest radiographs per patient per day, length of ICU stay, ICU mortality) have done: applying a restrictive/on-demand strategy with respect to chest X-ray ordering. The results of their studies (in spite of the inconsistencies) consistently show that a reduction in the use of bedside radiography might decrease costs without adversely affecting patient outcomes [Leong CS, et al, 2000].

Safety of the patient along the pathway of health care remains of paramount importance.

A couple of studies investigating chest radiography ordering strategy in mechanically ventilated adult patients [Hejblum G, et al, 2009] and in patients in the first 24 hours after cardiac surgery [Tolsma M, et al 2011; Tolsma M, et al, 2014; Tolsma M, et al, 2015] showed that adopting an on-demand strategy did not lead to compromise in patient care. However, the authors of these studies have cautioned that clinical

assessment alone is often inadequate in predicting significant abnormalities that can easily be detected by chest radiography.

Neither of these studies [Tolsma M, et al, 2011; Tolsma M, et al, 2014; Tolsma M, et al, 2015; Hejblum G, et al, 2009] nor a more recent meta-analysis [Ganapathy A, et al, 2012] were able to assess the potential harm produced by missed findings. In their conclusions the authors of these studies express the uncertainty of abandoning routine chest radiography in patients admitted to the intensive care unit.

In an even more recent study [Tolsma M, et al, 2015] investigating the indications for selective chest radiography in the first 24 hours after cardiac surgery, the combined diagnostic efficacy for routine and on-demand chest X-ray was 45%. The therapeutic efficacy was 4% for the on-demand chest X-rays, while the routine chest X-rays had a therapeutic efficacy of only 0.6%. These results allowed the authors of this study to reduce the number of chest X-rays performed in the first 24 hours after cardiac surgery, for clearly defined indications.

The debate regarding specific indications for chest X-rays in ICU patients and the safety of abandoning the practice of performing routine chest radiography after cardiac surgery is still on-going. It reflects uncertainty with regards to abandoning a reflex need (that doctors often have) for reassurance in connection with the safety of one of the most critically ill patient population groups in hospital.

There might be other imaging modalities available for these very sick patients, particularly following admission to ICU after cardiac surgery. These imaging modalities (ultrasonography, tomography) require investigation and thorough analysis and comparison before abandoning the one that seems to be efficient in our resource limited environment. Elimination of any bias in assessing the best tool for a specific intervention can sometimes be difficult.

Our study is retrospective - this might remove certain type of bias. All medical assessments and chest radiographs were carried out without a thought of ever having someone come to scrutinise one's medical skills.

The results of this study are a true reflection of the doctors' practice in Groote Schuur Hospital, in D22 Cardiothoracic ICU. The use of clinical records for the audit does lend itself to bias for the following reasons:

- Incomplete medical records;
- Illegible handwriting; as well as due to the
- Multiple assumptions that were made.

Other factors that might introduce bias consist of the lack of comparison with other imaging modalities - due to limited financial resources and lack of expertise in this respect.

3.4. Rationale for the study

Although frequently advised, the safety of abandoning routine chest radiography following cardiac surgery remains uncertain.

Between the need to contain the rising costs of health care and the obligation to preserve patient safety, this idea of determining the clinical value of routine chest X-ray following admission to ICU after cardiac surgery, comes naturally. It is the first study of this kind done in Africa: assessment of the utility of the routine chest radiography after cardiac surgery in a limited resource environment.

Bedside radiography has become an essential adjunct to the physical examination of patients following cardiac surgery. Despite its limitations, it is relatively cheap and safe, easily available and often reveals abnormalities that may not be detected by clinical examination.

Other imaging modalities like computed tomography, transthoracic echocardiogram, ultrasound, might have higher sensitivity than chest

radiography but are more expensive and require technical expertise in manipulation/performance and interpretation of results.

Ability to safely restrict ordering of chest X-rays, if evidence supports it, will allow modification of the cardiac surgery care pathway in our cardiac ICU. Allocation of resources will be spared to advancement of medical knowledge in other areas of health care and this will be our (though small) contribution to better health care for all.

3.5. The need for further research

Most scientific articles investigating the value of daily routine bedside chest radiography have focused on diagnostic and management efficacy [Leong CS, et al, 2000]. Based on the results of the said studies recommendations to abandon routine chest radiography have been advocated and the application of an on-demand strategy advised, only when pathophysiological changes dictate a need for therapeutic intervention.

No study has attempted to evaluate the impact on patient management as well as the impact of missed abnormalities, with their potential complications and delayed interventions on patients' outcomes.

Few studies have attempted to assess the role and value of routine chest radiography on morbidity and mortality – outcome efficacy.

Future research must investigate the following aspects:

- Randomization of patients for receiving or restricting ordering of bedside chest radiography;
- Analysis of chest radiograph ordering strategy on outcomes like: length of ICU stay, length of ventilation, mortality;
- Incidence of missed findings by adopting an on-demand strategy of chest X-ray ordering and their impact on

morbidity, length of ICU stay, re-admission rates to ICU, mortality;

- Identification of certain patient population groups that might benefit from routine chest radiography;
- Ability to modify cardiac surgery pathway of care should the evidence show lack of benefit in ordering routine chest X-ray;
- Identification of other imaging modalities that compare, and/or are better at imaging in ICU after cardiac surgery.

Bibliography:

1. Archer C, Levy AR, McGregor M, 1993 *“Value of routine preoperative chest X-rays: a meta-analysis”* Can J Anaesth 40 (11): 1022-1027.
2. Barak M, Markovits R, Guralnik L, Rozenberg B, Ziser A, 1997, *“The utility of routine postoperative chest radiography in the postanesthesia care unit”* J Clin Anesth, 9: 351-354.
3. Baskett RJF, Ghali WA, Maitland A, Hirsch GM, 2002, *“The intra-aortic balloon pump in cardiac surgery”* Ann Thorac Surg, 74: 1276-1287.
4. Bekemeyer WB, Crapo RO, Calhoon S, Cannon CY, Clayton PD, 1985, *“Efficacy of chest radiography in a respiratory intensive care unit”* Chest, 88 (5): 691-696.
5. Brunnel W, Coleman DL, Schwartz DE, Peper E, Cohen NH, 1989, *“Assessment of routine chest roentgenograms and the physical examination to confirm endotracheal tube position”* Chest, 96 (5): 1043-1045.
6. Eisenberg RL, Khabbaz KR, 2001, *“Are chest radiographs routinely indicated after chest tube removal following cardiac surgery?”* Am J Roentgenol, 197: 122-124.
7. Elshaug AG, Bessen T, Moss JR, Hiller JE, 2010, *“Addressing “waste” in diagnostic imaging: some implications of comparative effectiveness research”* J Am Coll Radiol, 7: 603-613.
8. Fryback DG, Thornbury JR, 1991, *“The efficacy of diagnostic imaging”* Med Decis Making, 11: 88-94.
9. Ganapathy A, Adhikari NKJ, Spiegelman J, Scales DC, 2012, *“Routine chest X-rays in intensive care units: a systematic review and meta-analysis”* Crit Care, 16: R68.
10. Geijer M, Ivarsson L, Gothlin JH, 2012 *“A retrospective analysis of the clinical impact of 939 chest radiographs using the medical records”* Radiology Research and Practice, Article ID 862198.

11. Geijer M, Gothlin JH, 1998, "*Symptoms or no symptoms: effectiveness of chest radiography*" Acad Radiol, 5 (suppl 2): S333-S335.
12. Gladwin MT, Slonim A, Landucci DL, Gutierrez CD, Cunnion ER, 1999, "*Cannulation of the internal jugular vein: is postprocedural chest radiography always necessary?*" Crit Care Med, 27 (9): 1819-1823.
13. Graat ME, Kroner A, Spronk PE, Koevaar JC, Stoker J, Vroom MB, 2007, "*Elimination of daily routine chest radiographs in a mixed medical-surgical intensive care unit*" Intensive Care Med, 33: 639-644.
14. Gray P, Sullivan G, Ostryzniuk P, McEwen TAJ, Rigby M, Roberts DE, 1992, "*Value of postprocedural chest radiographs in the adult intensive care unit*" Crit Care Med, 20 (11): 1513-1518.
15. Gurney WJ, 1995 "*Why chest radiography became routine*" Radiology, 195 (1): 245-246.
16. Hall JB, White SR, Karrison T, 1991 "*Efficacy of daily routine chest radiographs in intubated, mechanically ventilated patients*" Crit Care Med, 19 (5): 689-693.
17. Hejblum G, Chalumeau-Lemoine L, Loos V, Boelle P, 2009, "*Comparison of routine and on-demand prescription of chest radiographs in mechanically ventilated adults: a multicentre, cluster randomised, two-period crossover study*" Lancet, 374: 1687-1693.
18. Hendrikse KA, Gratama JWC, Hove W, Rommes JH, Schultz MJ, Spronk PE, 2007, "*Low value of routine chest radiographs in a mixed medical-surgical ICU*" Chest, 132 (3): 823-828.
19. Henschke CI, Pasternack GS, Schroeder S, Hart KK, Herma PG, 1983, "*Bedside chest radiography: diagnostic efficacy*" Radiology, 149: 23-26.
20. Henschke CI, Yankelevitz DF, Wand A, Davis S, Shiau M, 1997, "*Chest radiography in ICU*" Clinical imaging, 21: 90-103.

21. Hornick PI, Harris P, Cousins C, Taylor KM, Keogh BE, 1995, *“Assessment of the value of the immediate postoperative chest radiograph after cardiac operation”* Ann Thorac Surg, 59: 1150-1154.
22. Ios V, Galbois A, Chalumeau-Lemoine L, , 2011, *“An integrated approach for prescribing fewer chest X-rays in the ICU”* Ann Int Care, 1: 4.
23. Kager LM, Kroner A, Binnekade JM, Gratama JW, Spronk PE, Stoker J, Vroom MB, Schultz MJ, 2010, *“The value of routinely obtained chest radiographs on admission to a mixed medical-surgical intensive care unit”* J Intensive Care Med, 25 (4): 227-232
24. Karthik S, O’Regan DJ, 2006 *“An audit of follow-up chest radiography after coronary artery bypass graft”* Clinical Radiology, 61: 616-618.
25. Khan T, Chawla G, Daniel R, Swamy M, Dimitri WR, 2008 *“Is routine chest X-ray following mediastinal drain removal after cardiac surgery useful?”* Eur J Cardiothorac Surg, 34: 542-544.
26. Kripostal M, Shlobin OA, Schwartzstein RM, 2003 *“Utility of daily routine portable chest radiographs in mechanically ventilated patients in the medical ICU”* Chest, 123 (5): 1607-1614.
27. Leong CS, Cascade PN, Kazerooni EA, Bolling SF, Deeb GM, 2000, *“Bedside chest radiography as part of a postcardiac surgery critical care pathway: a means of decreasing utilization without adverse clinical impact”* Crit Care Med, 28(2): 383-388.
28. Loop JW, Lusted LB, 1978 *“American College of Radiology diagnostic efficacy studies”* Am J Roentgenol, 131: 173-179.
29. Lotano R, Gerber D, Aseron C, Santarelli R, Pratter M, 2000, *“Utility of postintubation chest radiographs in the intensive care unit”* Crit Care, 4: 50-53.

30. Malnick S, Duek G, Beilinsori N, 2010, "*Routine chest X-ray on hospital admission: does it contribute to diagnosis or treatment?*" IMAJ, 12: 357-361.
31. Mets O, Spronk PE, Binnekade J, Stoker J, 2007, "*Elimination of daily routine chest radiographs does not change on-demand radiography practice in post-cardiothoracic surgery patients*" J Thorac Cardiovasc Surg, 134 (1): 139-144.
32. Oba Y, Zaza T, 2010, "*Abandoning daily routine chest radiography in the intensive care unit: meta-analysis*" Radiology, 255 (2): 386-395.
33. O'Brien W, Karski JM, Cheng D, Carrol-Munro J, Penston C, Sandler A, 1997, "*Routine chest roentgenography on admission to intensive care unit after heart operations: is it of any value?*" J Thorac Cardiovasc Surg, 113: 130-133.
34. Owen RL, Cheney FW, 1987, "*Endobronchial intubation: a preventable complication*" Anesthesiology, 67 (3): 255-257.
35. Palesty JA, McKelvey AA, Dudrick SJ, 2000, "*The efficacy of X-rays after chest tube removal*" Am J Surg, 179: 13-16.
36. Price MB, Grant MJ, Welkie K, Chellis PNP, 1999 "*Financial impact of elimination of routine chest radiographs in a pediatric intensive care unit*" Crit Care Med, 27 (8): 1588-1593.
37. Rao PSR, Abid Q, Khan KJ, 1997, "*Evaluation of routine chest X-rays in the management of the cardiac surgical patient*" Eur J Cardiothor Surg, 12: 724-729.
38. Robin ED, Burke CM, 1986, "*Routine chest X-ray examinations*" Chest, 90 (2): 258-262.
39. Sepehripour AH, Farid S, Shah R, 2012, "*Is routine chest radiography indicated following chest drain removal after cardiothoracic surgery?*" ICVTS, 14: 834-838.
40. Stevens JJWM, Booth JV, Little J, Gopinath S, Ghosh S, Kneeshaw JD, Oduro A, 1995, "*The value of immediate*

- postoperative chest radiography in adult cardiac surgery*” BJA, 74: 56 A110.
41. Suh RD, Genshaft SJ, Kirsch J, Kanne JP, Chung JH, Donnelly EF, Ginsburg ME, 2014, “ACR Appropriateness Criteria: intensive care unit patients” www.acr.org/ac.
 42. Tape TG, Mushlin A, 1986, “The utility of chest radiographs” Ann Int Med, 104 (5): 663-670.
 43. Tolsma M, Kroner A, van den Hombergh CLM, Rosseel P, Rijpsma T, Dijkstra HA, Bentala M, Schultz MJ, van der Meer NJM, 2011, “The clinical value of routine chest radiographs in the first 24 hours after cardiac surgery” Anesth Analg, 112 (1): 139-142.
 44. Tolsma M, Bentala M, Rosseel PMJ, Gerritse B, Dijkstra H, Mulder PG, van der Meer NJ, 2014, “The value of routine chest radiographs after minimally invasive cardiac surgery: an observational cohort study” J Cardiothorac Surg, 9: 174.
 45. Tolsma M, Rijpsma TA, Rosseel PMJ, Scohv TV, Bentala M, Mulder PG, van der Meer NJ, 2015, ‘Defining indications for selective chest radiography in the first 24 hours after cardiac surgery’ J Thorac Cardiovasc Surg, 150 (1): 225-229.
 46. Trotman-Dickenson B, 2003, “Radiology in the intensive care unit (Part I)” J Intensive Care Med, 18 (4): 198-210.
 47. Veldkamp WJH, Kroft LJM, Geleijns J, 2009, “Dose and perceived image quality in chest radiography” Eur J Radiol, 72: 209-217.
 48. Verma V, Vasudevan V, Jinnur P, Nallagatla S, Majumdar A, Arjomand F, Scott-Reminick M, 2011, “The utility of routine admission chest X-ray films on patient care” Eur J of Int Med, 22: 286-288.
 49. Whitehouse MR, Patel A, Morgan JA, 2009, “The necessity of routine post-thoracostomy tube chest radiographs in post-operative thoracic surgery patients” Surgeon, 7 (2): 79-81.

CHAPTER FOUR

Aims and Objectives

Academic, as well as all the other state hospitals are facing increasing budgetary constraints as an expression of mounting pressure to reduce government spending. In spite of these financial considerations there is an ever increasing demand to maintain the standards of high academic performance and to promote the implementation of evidence-based medical practice.

Advances in medical technology with the ability to sustain and support the very young and the very old, in increasing numbers, with complex pathologies, have contributed to overall rising health care spending. Intensive care units are no exception from this and they do take up a considerably large portion of the hospital budget.

Policy makers, the public and clinical decision makers need to come together in an orchestrated effort to provide the best health care we can - given the particular socio-economic circumstances that South Africa has to contend with.

This is why increased scrutiny is placed on diagnostic technologies and tests. If evidence shows that restricting ordering of these tests (radiography included) proves beneficial in saving costs without compromising safety and health care, this might free up resources for advances and progress in other areas of medical practice and health care.

4.1. Aims

The aim of the study was to determine the clinical role and importance (in a limited resources environment) of a relatively low cost, low radioactive dose, easily accessible, chest imaging modality - the routine chest X-ray -

used as a diagnostic tool in the first 24 hours following admission to ICU after cardiac surgery.

In a nutshell the study was done in order:

- To determine the incidence of significant abnormalities/findings on the post-operative chest X-ray;
- To ascertain the frequency of therapeutic interventions based on the significant chest X-ray findings; and
- To identify and analyse the role of serial chest radiographs in detecting evolving/progressing pathology.

The spiralling costs of health, health maintenance, health prevention, and health care have led to an augmentation in the interest of determining the factors/methods that can reduce these costs in an efficient and effective manner, while, at the same time preserving patient safety.

Observations that various forms of testing (radiology included) are often of minimal value suggest all such “routine” tests should be justified by careful assessment.

The study also needed to answer the following questions:

- Do routine chest X-rays performed in ICU in the first 24 hours after cardiac surgeries add any value to the management of the cardiac surgery patients?
- Is the performance of these chest X-rays a protocol-driven practice?
- If routine chest radiography does not add any diagnostic or therapeutic value to the management of post cardiac surgery patients, can we then modify the cardiac surgical pathway of care and save costs without exposing patients to adverse outcomes?

The diagnostic and therapeutic efficacy will be used as instruments for assessing the impact of the bedside chest radiography on the clinical management of these patients.

4.2. Objectives

The objectives of the study are:

- To have all chest radiographs done in the first 24 hours after admission to ICU analysed and reported upon by a consultant diagnostic radiologist specializing in chest radiography;
- To analyze all clinical records (including the Cardiothoracic Database) in order to identify clinical findings or decisions that led to the ordering of chest X-ray; and
- To evaluate the correlation between the findings on clinical exam and the significant findings on the chest radiograph.

CHAPTER FIVE

Methodology

This chapter describes the methodology used in the study and the processes involved in validating the role of the chest radiography upon admission to ICU following cardiac surgery.

Ethics approval and the identification process of participants will be outlined.

The statistical methods used to analyse the data will also be described.

5.1. Methodology

This is a retrospective, single centre audit, performed at a tertiary teaching hospital, namely Groote Schuur Hospital, in D22 Cardiothoracic Intensive Care Unit (six ventilated beds) investigating the use of chest radiography in post cardiac surgery patients admitted to the unit over a period of a year, from 1st of September 2013 to 1st of August 2014.

5.2. Ethics approval

The study protocol was approved by the Ethics Committee of the Faculty of Health Sciences University of Cape Town (HREC REF: 845/2014).

Permission to access medical records was granted by Dr Bernadette Eick, Chief Executive Officer of Western Cape Provincial Hospitals.

Professor Peter Zilla, Head of the Department of Cardiothoracic Surgery, granted permission to access the main Cardiothoracic Database.

5.3 Participants

The study population consisted of all cardiac surgical patients admitted to D22 Cardiothoracic ICU from the 1st September 2013 to the 31st August 2014. This included all patients who had undergone cardiac surgery by conventional full median sternotomy, as well as those that had undergone minimally invasive cardiac surgery (during that period).

Demographic data were collected for all patients. The mean age, mean number of chest radiographs per patient, and median duration of ICU and hospital stay were calculated.

In our practice, cardiac surgery patients are transferred to the D22 ICU after the surgical procedure.

On arrival in the ICU the patient is seen by a senior registrar. A clinical examination is performed, blood samples are taken and a routine chest radiograph is obtained to ensure proper position of the endotracheal tube, nasogastric tube, indwelling lines, invasive devices, as well as to determine the presence of pneumothorax, fluid overload, atelectasis or any other major complication .

All newly admitted patients, with the results of all special investigations, including chest X-rays, are assessed by senior intensivists. Management is instituted based on clinical and special investigation findings. Subsequent chest X-rays are obtained either on routine or on demand basis.

5.4. Consent

There was no need for informed consent because no intervention was instituted on the participants.

The de-identification process applied ensured that the anonymity of the participants/patients was maintained.

5.5. Chest radiographs

All chest X-rays that were performed in the first 24 hours of the participants' stay in ICU formed the major part of the study.

All available medical records, including doctors' entries, nurses' records, physiotherapist notes, ICU charts, prescription charts, request forms for the chest radiographs, as well as the discharge summaries were analysed.

The chest X-rays were retrieved from the Groote Schuur Hospital Picture Archiving and Communication System (PACS). They were analysed and interpreted by a consultant diagnostic Radiologist specializing in chest radiography.

All clinical records were analysed to identify the clinical findings or decisions that had led to the ordering of chest X-ray.

The Cardiothoracic Database was also subjected to thorough scrutiny and any new relevant clinical information was recorded.

5.6. Time frame

The collection of the data commenced at the end of September 2014 and was successfully completed in the first week of May 2015.

5.7. Challenges

The greatest challenge was the retrieval of the information from the clinical records.

Some medical records were incomplete. Illegible hand writing was another issue that complicated the matters further.

In a few cases, there was no mention of radiological outcome in the medical records.

On the other hand, the ICU charts were the best tools in providing information with respect to the clinical progress of the patients/participants, and this was followed only by physiotherapist' notes.

The other delay came from the Radiologist who had to try and fit in the interpretation of the research chest radiographs to her busy schedule.

5.8. Assumptions

During the execution of the study, the following assumptions were made:

- All patients had been evaluated clinically before their chest X-rays were reviewed;
- A few medical records were not revealing as to the clinical progress of the patients , and as a result changes in medication as recorded in the case notes or prescription charts led us to believe that there were changes in treatment;
- The presence of the following phrases in the doctors' notes "no abnormality detected" (NAD) on chest/respiratory/clinical examinations, was taken to mean that there were no significant clinical findings on the examination of the chest.

5.9. Application of methodology

The nature of this study makes it unavoidable the repeated mentioning of some of the results whilst discussing the methodology of the research. To minimize such repetition some of the results that have been mentioned during the discussion of the methodology will not be mentioned again under the discussion of the results of the study.

5.9.1. Chest X-ray indications

All chest X-rays that had been performed were categorised according to the *indication*, i.e. routine or on-demand radiographs.

The chest X-rays were *numbered* according to *the sequence* in which they had been done. ‘*CXR1, CXR2, and CXR3*’ have been assigned and refer to the first, second and third chest X-ray performed within the first 24 hours post cardiac surgery, respectively.

The proportion (and frequency) of chest X-rays falling into each category is provided below. For each aspect of *interest* (for example, **Indication**), the results are presented in a table. The data is both stratified by the CXR number (**1, 2 or 3**) and analysed all together (see **CXR Number**).

<i>CXR numbering</i>	<i>Indication</i>	<i>Count</i>	<i>Percentage</i>	<i>Confidence interval</i>
1	Routine	299	99.01	97.12 - 99.79
	On-demand	3	0.99	0.21 – 2.88
Total Number of Participants who had the first CXR Performed		302	100	
2	Routine	180	72.58	66.58 – 78.03
	On-demand	68	27.42	21.97 – 33.42
Total Number of Participants who had the second CXR Performed		248	100	
3	Routine	11	40.74	22.39 – 61.2
	On-demand	16	59.26	38.8 – 77.61
Total Number of Participants who had the third CXR Performed		27	100	
Total CXRs within first 24 Hours post cardiac surgery	Routine	490	84.92	81.74 – 87.74
	On-demand	87	15.08	12.26 – 18.26
Total Number of CXRs performed		577	100	

Analysis of the data obtained shows:

- There are 302 first chest radiographs in total and there are 302 first chest X-rays with recorded indication categories;
- Of the 302 first chest X-rays, 299 were performed as *routine* radiographs and 3 were performed *on-demand*;

The proportion of first chest X-rays performed as *routine* is therefore 99.01% (with 95% confidence interval: 97.12% -99.79%), and the proportion of those performed *on-demand* is 0.99% (95% CI: 0.21%-2.88%);

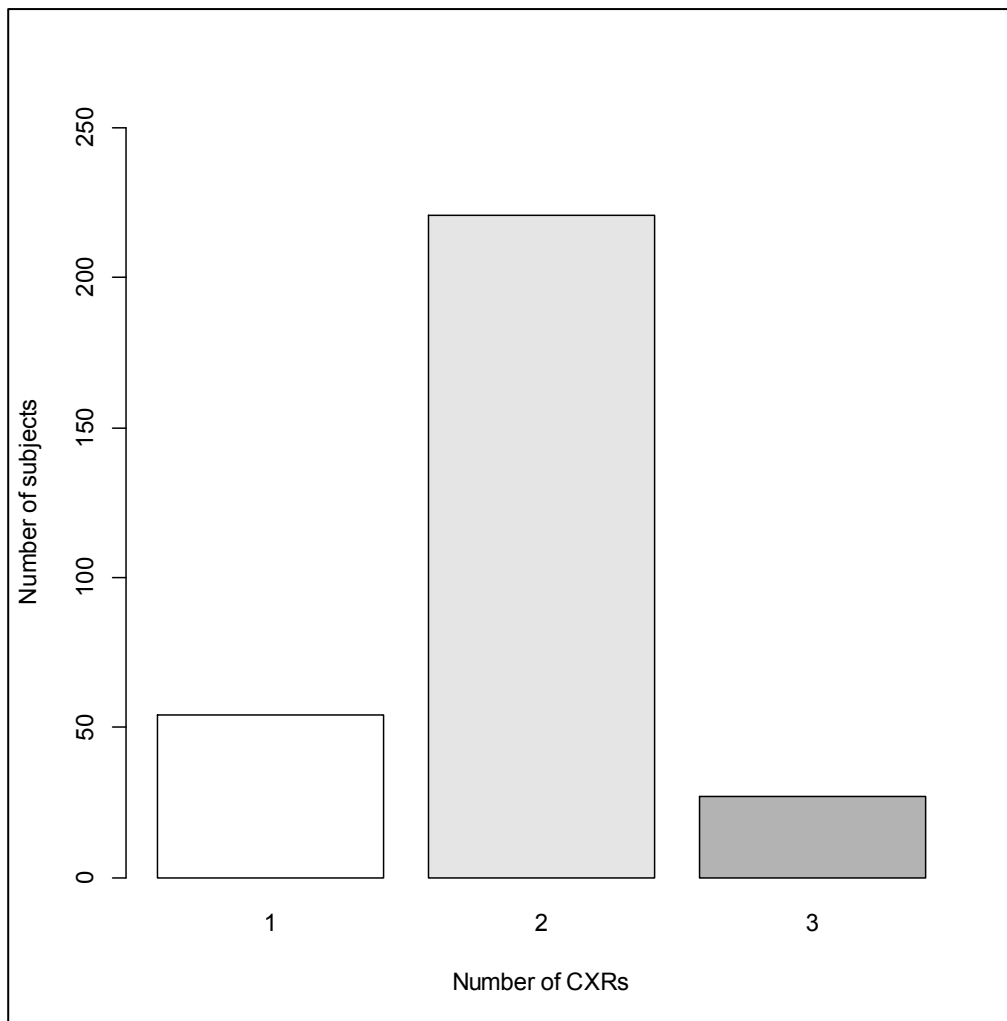
For CXR 1 there were 3 *on-demand* CXRs. The clinical reasons for these on-demand chest radiographs were:

- Pre-operative pulmonary oedema;
- Respiratory failure; and
- Intra-operative pulmonary oedema.

248 participants had a 2nd CXR done. The indications for these CXRs varied from routine to on-demand CXR.

27 participants from the 248 went on to have a 3rd CXR.

The distribution of the CXRs done in the first 24 hours following ICU admission is depicted by the bar-graph below.



From the above bar graph one can see that 54 patients had only CXR1 performed (one CXR) on them in the first 24 hours of their admission to ICU.

221 had CXR1 and CXR2 done and this translates to two CXRs per patient in the first 24 hours of their stay in ICU.

27 patients had CXR1, CXR2 and CXR3 performed and this adds up to three CXRs per patient in the first 24 hours.

54 participants had CXR1 only. This can be calculated from the following:
 $302 \text{ less } 248 = 54.$

221 participants had CXR1 and CXR2. This can be calculated from the following: 248 less 27 results in 221.

The 27 participants went on to have CXR3 which was the 3rd CXR.

Considering all chest radiographs, 490 of the 577 CXRs were routine chest X-rays. In other words, 84.92% (95% CI: 84.74%-87.78%) of all chest radiographs were routine.

5.9.2. Classification and analysis of Radiologist findings

The significant findings by the Radiologist were analysed in a systematic fashion. Abnormalities already present in the previous chest radiographs were not considered, unless there was significant change in the abnormality, e.g. linear or segmental atelectasis having deteriorated to a complete collapse of a lobe. Only new findings were analysed [Tolsma M, et al, 2011].

The Radiologist findings were then categorised into either ***clinically significant or non-significant abnormalities/findings***.

Clinically significant findings are defined as chest X-ray findings that prompted intervention by primary ICU physician and/or cardiothoracic surgeon.

Significant radiological findings

- 76 (30.64%) complete lobar collapse either left, right or middle lobe - most often the lower lobes were involved;
- 49 (19.75%) significant bi-basal/bilateral atelectasis;
- 1 (0.4 %) complete lung collapse;
- 41 (16.53%) consolidation/opacification/ infiltrates;
- 17 (6.85%) fluid overload/pulmonary oedema;
- 11 (4.43 %) pneumothorax, of whom, only two had ICDs inserted;

- 2 (0.8 %) pneumopericardium;
- 4 (1.61. %) pneumomediastinum;
- 1 (0.4%) massive pleural effusion;
- 12 (4.8 %) significant bilateral effusions;
- 2 (0.8 %) cardiac tamponade, caused by a bleeding LIMA;
- 1 (0.4 %) mediastinal haematoma with the CVP catheter in the right subclavian vein and this prompted the radiologist to think that the haematoma was probably result of a traumatic insertion of the CVP catheter;
- 1 (0.4 %) had a sliver of right sub-phrenic intraperitoneal free air.

Significant findings related to invasive devices

- 1 patient had two right internal jugular vein catheters;
- 10 patients had the central venous catheter tip in the right atrium;
- 1 had the CVP catheter tip in the right brachiocephalic vein;
- 1 had the CVP catheter tip in the right subclavian vein;
- 1 had the tip of CVP catheter curled upwards in the SVC with probable kink;
- 2 patients had the CVP catheter tip in the distal right internal jugular vein;
- 1 patient had the NG tube curled in the proximal thoracic oesophagus;
- 1 patient had the NG tube curled in the stomach;
- 1 patient had the intercostal drain kinked;
- 1 patient had the endotracheal tube in the right bronchus.

There are 20 (twenty) significant findings related to invasive devices. 16 (80%) relates to malposition of the CVP. 62.5% of the malpositioned CVPs are as a result of CVP tip location in the right atrium.

20% (2) involve the NG tube.

10 % (1) kinked intercostal drain.

The last 10 % (1) are related to the endotracheal tube.

The table below shows the distribution of the Radiologist findings as per relevant radiograph.

Classification of Radiologist findings.

CXR numbering	Radiologist findings	Count	Total	Percentage	Confidence interval
1	Significant	203	302	67.22	61.61 - 72.49
1	Non-significant	99	302	32.78	27.51 –38.39
2	Significant	87	247	35.08	35.42 –43.58
2	Non-significant	160	247	64.91	61.94 –69.84
2	Unknown	1	248		
3	Significant	12	27	44.44	38.07 –50.78
3	Non-significant	15	27	55.55	49.22 –61.93
All	Significant	302	577	52.34	46.04 - 59.32
All	Non-significant	275	577	47.66	44.7 – 53.04
All	Unknown	1	577		

Abnormalities related to malposition of invasive devices were mostly found in the first chest X-ray (CXR1).

NB: “**unknown**” refers to technical differences on acquiring the CXR, and this made interpretation of the CXR difficult.

5.9.3. Clinical findings

All the information gathered from doctors’ notes was used to classify clinical findings into *significant* and *non-significant findings*.

This was supplemented by nurses' notes, ICU charts, physiotherapist's notes, arterial blood gas results, chest X-ray request forms, and prescription charts.

In total there were 216 significant clinical findings based on all the relevant clinical notes.

Classification of clinical Findings

CXR numbering	Clinical findings	Count	Total	Percentage	Confidence interval
1	Non-significant	185	302	61.26	55.51 - 66.78
1	Significant	117	302	38.74	33.22 –44.49
2	Non-significant	163	248	65.73	59.46 –71.61
2	Significant	85	248	34.27	28.39 –40.54
3	Non-significant	13	27	48.15	28.67 –68.05
3	Significant	14	27	51.85	31.95 –71.33
All	Non-significant	361	577	62.56	58.47 - 66.53
All	Significant	216	577	37.44	33.47 –41.53

Clinical assessment findings were then matched to the corresponding chest radiograph.

5.9.4. Clinical findings versus Radiologist findings

We undertook to compare the Radiologist interpretation of the chest radiographs with information yielded by the clinical assessment. The following categories were used to compare Radiologist interpretation and clinical assessment:

- **“Discrepant”**: Radiologist findings did not match clinical assessment;

- “**Consistent**”: Radiologist findings and clinical assessment were similar;
- “**Unkown**”: Technical differences in acquisition of the CXR render comparison of the CXR with previous CXR difficult.

The percentage of chest radiographs that showed discrepancy between clinical assessment and chest X-ray findings were calculated. In 64 (11.09%) of cases discrepancy was noted.

Radiologist findings versus Clinical findings

CXR numbering	Radiologist findings vs Clinical findings	Count	Total	Percentage	Confidence interval
1	Discrepant	41	302	13.58	9.92 - 17.96
1	Consistent	261	302	86.42	82.04 –90.08
2	Discrepant	20	248	8.1	5.02 –12.23
2	Consistent	227	248	91.9	87.77 –94.98
2	Unknown	1	248		
3	Discrepant	3	27	11.11	2.35 –29.16
3	Consistent	24	27	88.89	70.84 –97.65
All	Discrepant	64	577	11.09	8.66 - 13.97
All	Consistent	512	577	88.89	86.03 –91.34
All	Unknown	1	577		

5.9.5. Therapeutic interventions

In order to assess the role of the chest radiographs in post operative care and management of the patients, analysis of the chest X-rays that led to any form of intervention was done.

Interventions prompted by the radiographic findings were noted and the percentages calculated.

Therapeutic interventions based on CXR findings:

CXR numbering	Intervention	Count	Total	Percentage	Confidence interval
1	Intervention	34	302	11.25	8.66 - 13.97
1	None	271	302	89.74	87.77 -94.68
2	Intervention	32	248	13.70	9.92 -17.96
2	None	214	248	85.89	82.84 -90.08
3	Intervention	11	27	40.74	33.22 -44.49
3	None	12	27	44.44	38.07 -50.78
3	Unknown	4	27		
All	Intervention	77	577	13.43	9.92 - 17.96
All	None	493	577	86.03	82.84 -92.56
All	Unknown	4	577		

The following *therapeutic interventions* were performed:

- Intercostal drain insertion;
- Reposition of invasive device;
- Diuretic therapy;
- Re-operation;
- Initiation or discontinuation of chest physiotherapy;
- Intubation;
- Initiation of non-invasive mechanical ventilation;
- Change in mechanical ventilation settings;
- Inotropic agents;
- Antimicrobial therapy.

NB: From the above table one can see that intervention on 4 participants out of the 27 that had a third CXR (CXR3) has been depicted as “**Unknown**”. The reason for this is that there were significant radiologist findings but no therapeutic interventions were effected according to clinical records.

5.9.6. Therapeutic intervention based on CXR indication

All the CXRs were then classified according to the indication and the resultant intervention, i.e. routine-intervention; routine-no intervention; on-demand-intervention; on-demand-no intervention.

The total number of CXRs that led to a therapeutic intervention was added together, the percentages and the confidence intervals were calculated accordingly.

From the 577 chest X-rays performed, therapeutic interventions were required in 42 cases (7.28%). This is the group of chest radiographs where significant pathological findings would have been missed and no essential therapeutic intervention would have been carried out if routine CXRs had not been performed. No intervention was required in 77.64% of the routine chest X-rays performed. 52 (9.01%) therapeutic interventions were carried out following the 88 on-demand CXRs.

Therapeutic intervention based on CXR indication

CXR numbering	Indication and Intervention	Count	Total	Percentage	Confidence interval
1	Routine intervention	31	302	10.26	8.66 - 13.97
1	Routine No intervention	268	302	88.74	87.77 –94.68
1	On-demand intervention	2	302	0.66	0.08 –2.37
1	On-demand No intervention	1	302	0.33	0.01-1.83
2	Routine Intervention	9	248	3.6	1.3-5
2	Routine No intervention	171	248	68.95	56.42 –64.58
2	On-demand Intervention	25	248	10.08	9.18 -14.61
2	On-demand No intervention	43	248	17.38	12.86 -22.82
3	Routine Intervention	2	27	0.74	7.46 – 43.7
3	Routine No intervention	9	27	33.33	16.52 -53.96
3	On-demand intervention	9	27	33.33	16.52 -53.96
3	On-Demand No Intervention	3	27	11.11	2.35-29.16
3	Unknown	4	27		
All	Routine Intervention	42	577	7.28	15.71 - 26.14
All	Routine No intervention	448	577	77.64	56.52 –67.74
All	On-demand Intervention	36	577	6.07	4.04 -10.75
All	On-demand No Intervention	47	577	8.15	4.38 – 11.27
All	Unknown	4	577		

The high lighted row is the row that was erroneously omitted.

5.9.7. Role of chest radiographs in evolving pathology

We analysed the number of chest X-rays that showed subsequent changes within the first 24 hours of ICU admission. We counted all those radiographs that showed progression of the clinical condition. We then looked at those that showed worsening of the clinical picture which ultimately led to therapeutic intervention.

The evolution of the pathological findings was classified as either “deterioration”, “improvement”, “no change” (referred to as “none”) or “Unknown” in the evolution of pathology.

NB: “None” means there **are** pathological findings on the CXRs but the said pathological findings do not change i.e there is neither deterioration nor improvement.

“Unknown” means that no pathological findings were detected on the said CXRs or there are no previous CXRs to compare with.

Chest radiographs in evolving pathology

CXR numbering	Chest X-ray Changes	Count	Total	Percentage	Confidence interval
1	Unknown	302	302	No Previous CXRs to compare with	
2	Improvement	42	248	17.43	12.86 - 22.82
2	Deterioration	91	248	37.76	31.62 - 44.21
2	None	108	248	44.81	38.43 - 51.33
2	Unknown	7	248	No pathological findings	
3	Improvement	3	27	11.11	2.35 – 29.16
3	Deterioration	9	27	33.33	16.52 - 53.96
3	None	15	27	55.56	35.33 - 74.52
All	Improvement	45	577	16.79	12.52 - 21.82
All	Deterioration	100	577	37.31	31.51 - 43.41
All	None	123	577	45.9	39.82 - 52.07
All	Unknown	309	577		

From the table above, 100 radiographs indicated a significant deterioration. This clinical deterioration ranged from worsening fluid overload, enlarging pleural effusions, increasing infiltrates/consolidations up to complete collapse of lung lobes.

As a result of these 100 radiographs, the following therapeutic interventions were performed:

- 2 patients needed re-intubation;
- 2 were put on non-invasive ventilation with PEEP;
- antidiuretic therapy was commenced in 6 patients;
- 1 patient was started on renal replacement therapy;
- antibiotic therapy was empirically started on 3 patients (after blood and tracheal aspirates had been sent away for microbiology, culture and sensitivity);
- according to the nurses' notes (sometimes these provided most information!) the ventilator settings had been changed in 3 patients.

In summary, out of 100 CXRs that showed radiological deterioration, 17 required therapeutic interventions.

5.9.8. Radiologist findings versus clinical finding *and* chest X-ray changes by intervention

Categories are based on two aspects (for example, Radiologist Finding versus Clinical Finding and CXR Changes). Instead of stratifying by CXR number, a third aspect (such as Intervention) is used to create strata.

We compared the discrepancies between the findings on the clinical assessment and the radiological findings as detected on the chest X-rays and how each of these categories impacted on therapeutic interventions.

The changes on the CXRs were categorized as either improvement or deterioration. Where the findings were consistent on both clinical and radiological assessment, irrespective of whether there was deterioration or improvement, this was categorized as “None” i.e no discrepancy. The CXR that did not have any pathological findings were classified as “unknown”

Out of the 577 CXRs, 310 CXRs did not show any pathologic changes, hence referred to as “unknown” on the Table. All the calculations were based on the 267 CXRs that showed either improvement or deterioration in radiologic findings

Example Interpretation

There were 184 routine chest radiographs, each with recorded categories (“consistent” and “discrepant”).

Of these, 86 routine radiographs had shown consistency between the Radiologist findings and the clinical assessment *and* revealed no changes in the condition. This amounts to 46.74% of routine X-rays (with 95% CI of 39.36 - 54.22%) showing no changes and being consistent with the clinical examination findings.

But, from the 184 routine radiographs performed, 5 (2.72 %) had discrepant Radiologist versus clinical findings and these X-rays showed radiological deterioration of the pathologic findings, namely:

- 2 cases of segmental atelectasis had changed to complete left lower lobe collapse;
- 1 had a right sided pleural effusion that had become massive and required an ICD insertion;
- 1 had worsening fluid overload expressed as increased septal thickening; and

- 1 had a complete collapse of left lower lobe and an enlarging right pleural effusion.

All these findings required intervention and would not have been predicted by physical assessment alone.

6 radiographs (7.23%) out of the 83 on-demand CXRs depicted deterioration which was visible on CXRs and naturally prompted intervention.

Radiologist findings versus clinical finding *and* chest X-ray changes by intervention

Indication	Compare Findings and Radiologic Changes	Count	Total	Percentage	Confidence interval
All	Discrepant Improvement	3	267	1.12	0.23 – 3.25
All	Discrepant Deterioration	11	267	4.12	2.07 - 7.25
All	Discrepant None	8	267	3	1.3 - 5.82
All	Consistent Improvement	42	267	15.73	11.58 - 20.66
All	Consistent Deterioration	88	267	32.96	27.35 - 38.95
All	Consistent None	115	267	43.07	37.05 - 49.25
All	Unknown	310	267		
On-demand	Discrepant Improvement	1	83	1.2	0.03 - 6.53
On-demand	Discrepant Deterioration	6	83	7.23	2.7 - 15.07
On-demand	Discrepant None	1	83	1.2	0.03 - 6.53
On-demand	Consistent Improvement	16	83	19.28	11.44 - 29.41
On-demand	Consistent Deterioration	30	83	36.14	25.88 - 47.43
On-demand	Consistent None	29	83	34.94	24.8 – 46.19
On-demand	Unknown	4	83		
Routine	Discrepant Improvement	2	184	1.09	0.13 – 3.87
Routine	Discrepant Deterioration	5	184	2.72	0.89 – 6.23
Routine	Discrepant None	7	184	3.8	1.54 – 7.68
Routine	Consistent Improvement	26	184	14.13	9.44 – 20.02
Routine	Consistent Deterioration	58	184	31.52	24.88 - 38.77
Routine	Consistent None	86	184	46.74	39.36 - 54.22
Routine	Unknown	306	184		

Explanatory note

“**Discrepant deterioration**” according to clinical assessment there is improvement but the CXRs show a deterioration which leads to therapeutic intervention.

“**Discrepant improvement**” clinical assessment paints a bleak picture but CXRs reveal no significant finding.

CHAPTER SIX

Thematic Analysis

This chapter analyses the chest radiographs performed for different clinical scenarios, e.g. after removal of chest drains. The rationale for this exercise was to assess the impact of these CXRs in terms of significant findings and subsequent interventions.

6.1. Routine chest radiographs in different categories

6.1.1. Chest X-rays *after removal of drains*

From all the chest radiographs performed, 150 had been performed following removal of chest drains.

Only 23 of these, i.e. 15.33%, needed an intervention based on the radiological findings:

- 3 had fluid overload; diuretics prescribed
- 1 was started on renal replacement therapy;
- 11 had total lobe collapse;
- 2 needed non-invasive ventilation with PEEP;
- 2 had developed pneumothoraces, of which, one needed an ICD;
- 1 had a massive pleural effusion that required re-insertion of an ICD;
- 1 had NG tube curled in the stomach;
- 1 had the CVP catheter tip in the right atrium;
- 1 had a small left pneumothorax with pneumopericardium;
- 2 had significant consolidation/infiltrates and fever;
- 1 was started on chemotherapy and radiotherapy; and

- 1 had worsening of bibasal atelectasis and needed persistent chest physiotherapy.

6.1.2. Chest X-rays following minimally invasive cardiac surgery

From the total chest radiographs performed, 33 were done on the 18 patients that had undergone minimally invasive cardiac surgery.

Out of the 33 CXRs, 6 radiographs had significant radiologist findings:

- 2 had complete right upper lobe collapse;
- 2 had pneumothoraces;
- 1 had complete collapse of left lower lobe; and
- 1 had significant bilateral effusions with underlying bibasal atelectasis.

6.1.3. Chest X-rays and *invasive devices*

Out of the 199 routine CXR1, 19 radiographs showed malpositioning of invasive devices (the nature of which has already been described).

From these, 18 were repositioned, except for one CVP catheter tip that remained in the right atrium and was detected in a subsequent radiograph. The clinical notes in this case did not show any further information.

One patient, who had complete collapse of the left lung, had endotracheal tube (ETT) pulled out of the right bronchus, ventilator settings changed and PEEP increased. Chest physiotherapy was also prescribed.

6.1.4. Chest X-rays in *post-pulmonary tuberculosis participants after cardiac surgery*

Mention needs to be made of the patients from our participants, who had pre-existent lung disease, particularly, pulmonary tuberculosis (PTB).

Of the 302 participants, 17, i.e. 5.62%, had previous pulmonary tuberculosis. According to the clinical records they had all completed their PTB treatment. None of the candidates suffered from PTB complications. The surgical procedures that they had were varied in nature.

Chest X-rays done in the post-pulmonary TB patients were 29. Out of these 29 radiographs, only one chest X-ray showed right middle lobe and left lower lobe atelectasis with small pleural effusions. No therapeutic intervention was undertaken.

The rest of the radiological findings ranged from normal post-surgical changes to small insignificant bilateral pleural effusions. No therapeutic intervention was documented on clinical records.

6.2. Research data analysis

Statistical analysis on the data retrieved was performed using SPSS (version22) R (64bit, version 3.1.3)

Mean and Median with confidence intervals applied on a sample so large – leads to very narrow Confidence Intervals. It is more informative to rather report a measure of the centre of the distribution (mean or median) and then the spread of the individual measurements (standard deviations or interquartile range) percentiles respectively.

Confidence Intervals using large sample approximations (the mean is approximately normally distributed) and the observed variance of age was used as a proxy for the true variance.

The confidence intervals were calculated using the inverse binomial cumulative distribution function, as outlined in L Ott & MT Longnecker, *A First Course in Statistical Methods*, 4th Ed, 2004.

The descriptive statistics are presented as median range.

CHAPTER SEVEN

Results

This chapter will give a concise report on the findings of the study.

The demographic data of the participants will also be discussed.

7.1. Demographic data

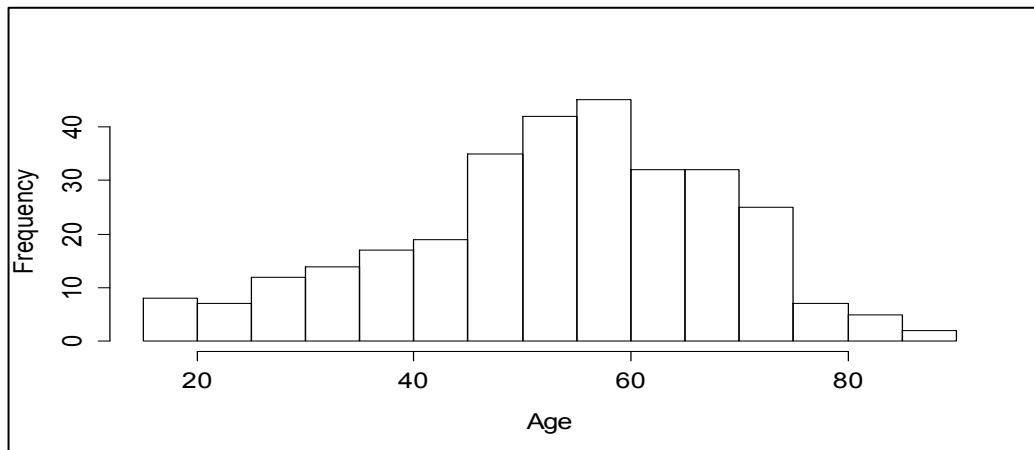
302 medical files of post cardiac surgery patients were included.

Mean age was 53.7 years.

Majority were females: 155 (51%). The rest, 147, were males (49%).

7.1.1. Age

The age of the participants is illustrated in the following bar graph:

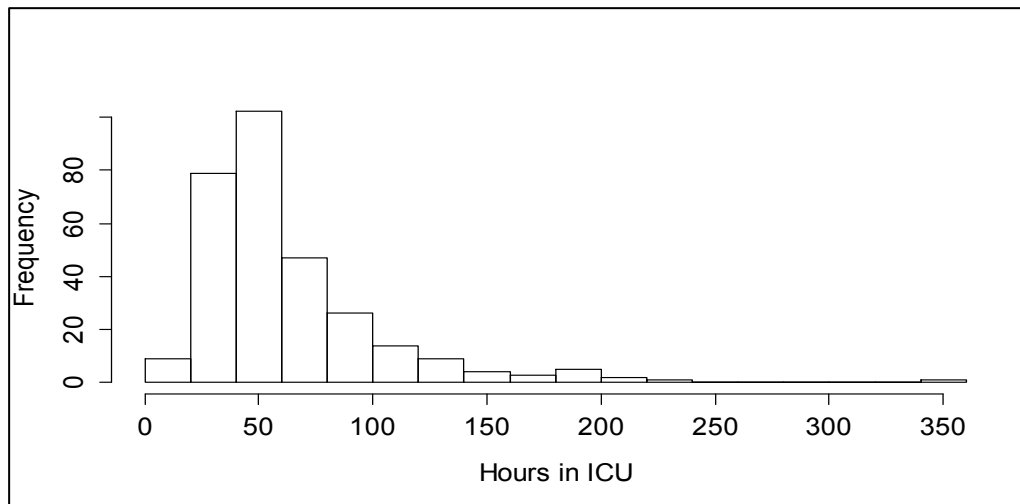


Mean: 53.7 years 95% CI for mean: 52.0-55.5 years.

Standard deviation of ages: 15.1 years CI calculating using large-sample

approximations (the mean is approximately normally distributed, and the observed variance of age was used as a proxy for the true variance).

7.1.2. Hours in ICU



Median: 44 hours; with 95% CI for median: 11-14 days.

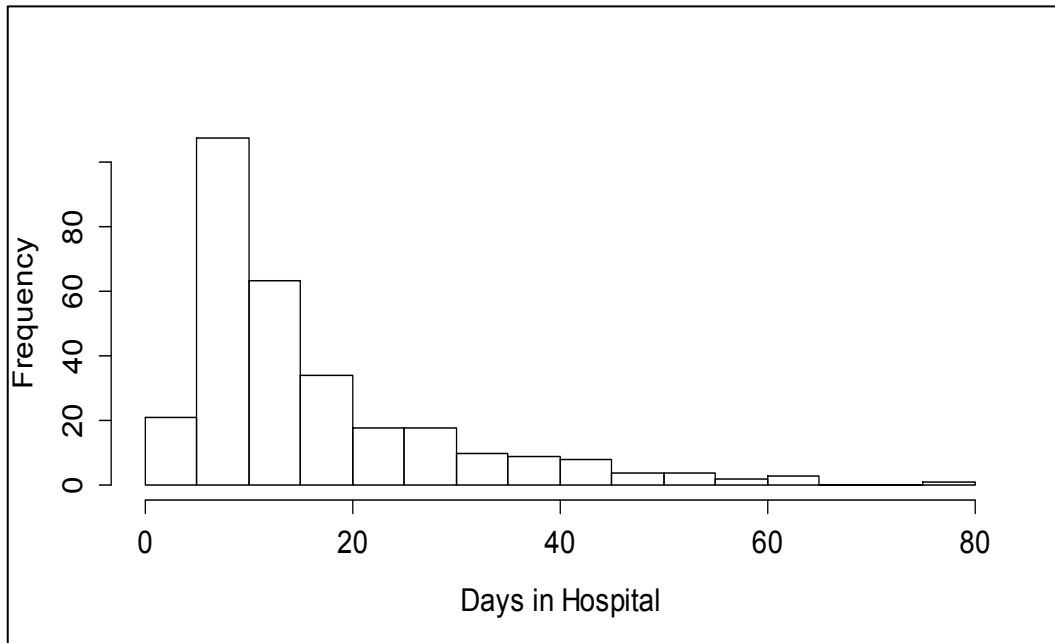
Percentiles of Hours in ICU:

0	Minimum	0
0.25	Lower quartile	39
0.5	Median	44
0.75	Upper Quartile	68
1	Maximum	347

Various methods have been proposed for estimating the confidence intervals (CI).

In this analysis, the CI is calculated using the inverse binomial cumulative distribution function, as outlined in L Ott and MT Longnecker, *A first course in statistical methods*, 4th ed, 2004.

7.1.3. Days in hospital



Median: 12 days 95% Confidence interval (CI) for median: 11-14 days

Percentiles of days in hospital:

0	Minimum	0
0.25	Lower quartile	8
0.5	Median	12
0.75	Upper Quartile	21
1	Maximum	76

7.1.4. Types of cardiac surgery procedures performed

Name of the procedure	Numbers of procedure	%
CABG*	106	35
Heart valve replacement	138	45.6
CABG* + Heart valve replacement	23	7.6
Minimally invasive cardiac surgery	18	5.96
Heart transplant	3	0.99
Others	14	4.6
Urgent surgery (mixed procedures)	14	4.6

7.2. Chest radiography

577 CXRs were performed, with a mean of 1.6 chest X-rays per patient.

From the 302 patients included in the study, 54 (17.88%) patients had only one CXR each in the first 24 hours of ICU admission. These patients had varied procedures and hence no specific pattern could be deduced.

Out of the 302 patients included in the study, 27 (8.9%) had a total of three chest X-rays each, and 16 (59.26%) of these were on demand radiographs. A total of 9 (33.33%) patients needed intervention based on radiological findings.

221 (73.18%) had two CXRs each, in the first 24 hours after cardiac surgery.

Clinical records failed to reveal a reason for the 2nd CXR on one participant that also had two CXRs in the first 24 hours of ICU admission.

Of 577 CXRs that had been done, 490 (84.92%) were routine CXRs and 88 (15.08%) were on-demand.

222 (38.47%) routine chest radiographs had significant radiological findings.

Out of the 222 routine chest X-rays with significant radiological findings, 42 (7.28%) led to therapeutic intervention.

4 patients had significant radiological findings on their chest radiographs but no therapeutic interventions had been recorded:

- The CVP catheter was still in the right atrium and not withdrawn despite the fact that the problem had been noted in the previous chest X-ray;
- Small left pneumothorax with pneumopericardium;
- Significant atelectasis/consolidation but the patient was still being investigated for pneumonia;
- Worsening left pleural effusion which was loculated and ultrasound guided drainage had been ordered.

The bulk of the results has already been presented under methodology and will not be presented again, in order to avoid repetition.

CHAPTER EIGHT

Discussion

This chapter focuses on the discussion and analysis of the results of the study.

A comparison with the results from previously published studies will be made.

8.1. Summary and data analysis

The aim of our study was to evaluate the role and importance of chest radiography in the management of patients admitted to ICU in the first 24 hours after cardiac surgery, by means of retrospective analysis of their medical records and Radiologist reports.

There is a view amongst academics that a retrospective study, based on medical records and radiology reports may be regarded as having less value than a prospective study. However literature has shown that medical notes and entries contain sufficient information to evaluate the clinical performance retrospectively [Geijer M, et al, 2012; Charny MC, et al, 1990].:

8.1.1. Diagnostic efficacy

The overall diagnostic efficacy for all post operative routine chest X-rays, performed in the first 24 hours, was 38.47%. This is comparable but somewhat higher than the reported diagnostic efficacy by other studies: 33.3% for a 2011 study [Tolsma M, et al, 2011] and 29.3% for a 2007 study [Mets O, et al, 2007].

High diagnostic efficacy – as high as 65% - for routine chest radiography was reported in articles published from the late 1980s and early 1990s.

8.1.2. Therapeutic efficacy

Many post-operative radiological findings tend to resolve spontaneously [Rao PSR, et al, 1997]. Majority of these minor post-operative findings like minor atelectasis and small effusions do not require any therapeutic intervention.

The therapeutic efficacy in our study was 7.28%. This is in contrast to all previous prospective homogenous studies whose therapeutic efficacies ranged from 0.65% to 4.5% [Tolsma M, et al, 2011; Tolsma M, et al, 2014; Tolsma M, et al, 2015].

The first study questioning the value of routine chest radiography after cardiac surgery [O'Brien W, et al, 1997] demonstrated that only 4.5% of patients (18 out of 404) required interventions based on the abnormalities detected on the chest films and had been missed by both clinical examination and laboratory assessment. None of the findings in this study were life threatening. In their conclusions, the authors of this study advocate that chest radiography should only be performed when the clinical evaluation indicates presence of pathophysiological changes that require confirmation and/or diagnosis [Leong CS, et al, 2000].

In summary, older, as well as more newer studies, have documented a low incidence of unexpected radiological abnormalities that have led to therapeutic interventions during patient care. The reason for the high yield in our study may probably be due to a higher prevalence of pulmonary pathology (though this was not very clear from our CXR reports) as well as different disease spectrum in this population group.

8.2. Radiologist findings versus clinical findings

In our study clinical findings and Radiologist findings were consistent in 91.76% of participants.

In 12 patients, i.e. 4.12 %, there were radiological signs of deterioration that required therapeutic intervention. In these patients the clinical examination failed to show signs of cardiopulmonary decompensation. It is in such situations that bedside radiography proves most useful, providing the clinicians with information they would, otherwise, not have had. Based on changes in the radiological findings, therapeutic interventions were then instituted.

Another study done in South Africa [Bhagwanjee S, Muckart DJJ, 1996] almost two decades ago looked at 164 ventilated patients in a surgical ICU and investigated the importance and the role of routine CXRs, and also whether clinical examination can predict radiological changes in ventilated patients. Clinical examination missed two (1%) out of 164 significant findings that were later confirmed by radiographic investigation. Based on this study the authors concluded that clinical examination can effectively help predict the need for chest radiograph.

However Oba and Zaza, 2010, have pointed out that the patient population in the Bhagwanjee's study was young and primarily admitted following trauma [Oba Y, Zaza T, 2010] and this could be a contributory factor to a low yield in Bhagwanjee's study.

A meta-analysis [Oba Y, Zaza T, 2010] of clinical trials (with a total of more than 7000 patients) that investigated the impact of abandoning routine CXRs have concluded that daily routine CXRs can "likely be eliminated without increasing adverse outcomes in adult patients in ICUs".

Nevertheless, studies [Tolsma M, et al, 2011; Tolsma M, et al, 2014; Tolsma M, et al, 2015] done in the last couple of years, specifically in patients following cardiac surgery, while emphasizing the partial

elimination of routine chest X-rays, at the same time, caution about the insensitivity of the clinical examination in detecting/predicting significant abnormalities that can otherwise be detected by chest radiography.

8.3. Chest X-rays following removal of ICDs

It was noted that over a year, during our study, 150 chest radiographs were performed following removal of chest drains. Out of the 23 that had significant radiological findings, only 13 required therapeutic interventions. The radiological findings were not only limited to pneumothoraces. Signs of fluid overload, lobar collapse, and pleural effusions were frequent findings on the X-rays. Only 2 pneumothoraces were identified, and only one (0.66 %) needed an ICD drain. Therapeutic efficacy all round was calculated to be 8.66%.

The pneumothorax yield after removal of the chest drain was significantly low in our study.

There are a number of studies [Mc Cormick JT, et al, 2002; Khan T, et al, 2008; Whitehouse MR, et al, 2009; Eisenberg RL, et al, 2011; Sepehripour AH, et al, 2012] spread over a period of 15 years that investigated the efficacy of chest X-ray following removal of chest drains in cardiothoracic surgery patients. From the oldest paper, to the more recent, authors of these studies conclude that abandoning of routine CXRs in this situation (post removal of chest drain) in postoperative cardiac patients is safe. The presence of respiratory and/or haemodynamic changes in the clinical condition of these patients identifies those that will benefit from chest radiography and the need for intervention.

The most recent article [Sepehripour AH, et al, 2012] analysed a total of 356 papers, of which 6 were selected as presenting the best evidence. They reported identification of abnormalities on routine chest radiographs ranging from 2 to 40%. Most of abnormalities were found on on-demand chest radiography (79%). Therapeutic efficacy was at best 4%.

Pathophysiological changes detected by clinical evaluation invariably led to therapeutic intervention.

A small non significant pneumothorax may not be important initially, but in certain circumstances (positive pressure ventilation) there can be serious implications (cardiorespiratory collapse as a result of tensioning) if the pneumothorax is not detected. Early detection by means of chest radiography can prevent morbidity and mortality.

Based on the results of our study and taking into account the above considerations we believe that our patient population in Groote Schuur Hospital benefits from chest radiography following removal of chest drain.

8.4. Radiological findings in minimally invasive cardiac surgery

In participants that had minimally invasive cardiac surgery, routine chest X-rays yielded a diagnostic efficacy of 18.18% and a therapeutic efficacy of 6.06%.

There was no differentiation between various methods of surgical access i.e. video-assisted thoracoscopy (VATS), antero lateral thoracotomy (port) access or mini-sternotomy in this study. This was done deliberately because the primary objective of the study was not based on comparison of different methods of minimally invasive cardiac surgery and their impact on the radiological findings.

These indices are still higher than those described in a recent study [Tolsma M, et al, 2014] where comparison was made between radiological findings in minimally invasive cardiac surgery and conventional cardiac surgery by full median sternotomy. The diagnostic efficacy for major findings for port access and VATS were 8.9% and 11% compared to 4.3% and 3.8 % in the mini- sternotomy and conventional surgery groups respectively. Therapeutic efficacy was 4.8% for port access and 1.5% for VATS. In this study the authors recommend the

performance of routine chest radiographs due to the higher yield in therapeutic efficacy in minimally invasive cardiac surgery patients.

8.5. Chest radiographs and invasive devices

Most of the malpositioned devices in our study were detected on the first routine CXR on arrival in the ICU. Out of 199 radiographs, 19 showed malposition of invasive devices. The diagnostic efficacy for malpositioning of invasive devices is 9.55%. With one exception, all the invasive devices were repositioned. This yields a therapeutic efficacy of 9.04%, which is significant.

The radiographic evaluation of positioning of these devices is important because of the potential serious complications arising from their insertion and use. Studies [Gladwin M, et al, 1999; Henschke CI, et al, 1997; Rubinowitz AN, et al, 2007] have shown that chest radiography has a high diagnostic accuracy for detecting malpositioned invasive devices in the ICU.

8.6. The role of serial chest radiographs in evolving pathology

100 chest radiographs illustrated progression of the pathological findings within 24 hours of arrival in the ICU. The pathological progression depicted by these CXRs led to the clinical deterioration of the participants that ultimately culminated in therapeutic interventions in 17 patients. This is a significant proportion of chest radiographs supporting the suggestion [Henschke CI, et al, 1997] that frequent imaging is clinically useful in detecting evolving pathology.

8.7. Radiological findings in post PTB patients after cardiac surgery

Of the 302 patients that form the bulk of participants in our study, 17 (5.6%) had previous pulmonary tuberculosis.

These 17 patients had 29 chest radiographs. Only one CXR (3.4%) had significant radiological findings/abnormalities. Although the Radiologist findings were significant, no therapeutic intervention was instituted, therefore yielding 0% therapeutic efficacy.

This was a surprise yield and contrary to our expectations. Pre-existing lung pathology has been identified as an important risk factor for post-operative pulmonary complications. The number of post-pulmonary TB participants is so small that one cannot draw any conclusions from the study results. One can cautiously infer that in the absence of PTB complications e.g. fibrosis, bronchiectasis, pulmonary hypertension, etc. the outcomes of these patients is almost the same as patients without predisposing factors. This should be interpreted with caution due to the small number of participants.

Summary of the discussion

From all the data obtained and the considerations outlined we conclude that in Groote Schuur Hospital bedside routine radiography has an important role as an essential effective supplement to the physical clinical evaluation of one of the most critically ill patients in ICU.

Bibliography:

1. Bhagwanjee S, Muckart DJJ, 1996, *“Routine daily chest radiography is not indicated for ventilated patients in a surgical ICU”* Int Care Med, 22: 1335-1338.
2. Charny MC, Roberts GM, Beck P, Webster D, Roberts C, 1990, *“How good are case notes in the audit of radiological investigations?”* Clin Radiol, 42 (2): 118-121.
3. Eisenberg RL, Khabbaz KR, 2011 *“Are chest radiographs routinely indicated after chest tube removal following cardiac surgery?”* Am J Roentgenol, 197: 122-124.
4. Geijer M, Ivarsson L, Gothlin JH, 2012 *“A retrospective analysis of the clinical impact of 939 chest radiographs using the medical records”* Radiology Research and Practice, Article ID 862198.
5. Gladwin M, Slonim A, Landucci DL, Gutierrez CD, Cunnion ER, 1999, *“Cannulation of the internal jugular vein: is postprocedural chest radiography always necessary?”* Crit Care Med, 27 (9): 1819-1823.
6. Henschke CI, Yankelewitz DF, Wand A, Davis S, Shiau M, 1997, *“Chest radiography in the ICU”* Clinical Imaging, 21: 90-103.
7. Khan T, Chawla G, Daniel R, Swamy M, Dimitri WR, 2008, *“Is routine chest X-ray following mediastinal drain removal after cardiac surgery useful?”* Eur J Cardiothorac Surg, 34: 542-544.
8. McCormick JT, O’Mara MS, Pappas PK, Caushay PF, 2002, *“The use of routine chest X-ray films after chest tube removal in postoperative cardiac patients”* Ann Thorac Surg, 74: 2161-2164.
9. Mets O, Spronk PE, Binnekade J, Stoker J, 2007, *“Elimination of daily routine chest radiographs does not change on-demand radiography practice in post-cardiothoracic surgery patients”* J Thorac Cardiovasc Surg, 134 (1): 139-144.

10. Oba Y, Zaza T, 2010, *“Abandoning daily routine chest radiography in the intensive care unit: meta-analysis”* Radiology, 255 (2): 386-395.
11. O’Brien W, Karski JM, Cheng D, Carrol-Munro J, Penston C, Sandler A, 1997, *“Routine chest roentgenography in admission to intensive care unit after heart operations: is it of any value?”* J Thorac Cardiovasc Surg, 113 (1): 130-133.
12. Rubinowitz AN, Siegel MD, Tocino I, 2007, *“Thoracic imaging in the ICU”* Crit Care Clin, 23: 539-573.
13. Sepehripour AH, Farid S, Shah R, 2012, *“Is routine chest radiography indicated following chest drain removal after cardiothoracic surgery?”* ICVTS, 14: 834-838.
14. Tolsma M, Kroner A, van den Hombergh CLM, Rosseel P, Rijpstra T, Dijkstra HA, Bentala M, Schultz MJ, van der Meer NJM, 2011, *“The clinical value of routine chest radiographs in the first 24 hours after cardiac surgery”* Anesth Analg, 112 (1): 139-142.
15. Tolsma M, Bentala M, Rosseel PMJ, Gerritse B, Dijkstra H, Mulder PG, van der Meer NJ, 2014, *“The value of routine chest radiographs after minimally invasive cardiac surgery: an observational cohort study”* J Cardiothorac Surg, 9: 174.
16. Tolsma, M., Rijpsma T.A., Rosseel, P.M.J., Scohv,T.V., Bentela, M., Mulder, P.G., van der Meer, N.J., 2015, *Defining indications for selective chest radiography in the first 24 hours after cardiac surgery* J Thorac Cardiovasc Surg, 150 (1): 225-229.
17. Whitehouse MR, Patel A, Morgan JA, 2009, *“The necessity of routine post-thoracostomy tube chest radiographs in post-operative thoracic surgery patients”* Surgeon, 7(2): 79-81.

CHAPTER NINE

Conclusions

This chapter will summarise the major observations of the study.

The limitations of this study will also be discussed.

Conclusions will be drawn and recommendations will be made based on the analysis of the data gathered by our study.

.

9.1. Reflections

It is well known that post-operative care is crucial for the success of all surgical procedures. Given the multidisciplinary approach to surgical care, it is important for anaesthesiologists to be involved and take a leading role in formulating protocols for an evidence-based surgical care pathway.

Patients must receive interventions that are evidence-based and are broadly accepted as the standard of care. Significant differences in the resource levels remain, some of which undermine the practice of safe patient care.

Routine diagnostic tests performed in the intensive care setting aid the clinician in the management of the post-operative patient, ideally without increasing costs or morbidity to the patient.

Bedside radiography is an essential supplement to the physical examination in the critically ill patient. It is readily available, easy and quick to perform at the patient's bedside, and is less expensive - compared to other imaging modalities. Physical examination is often limited or difficult to perform in patients who are intubated, uncooperative or unresponsive. The introduction of Picture Archiving and Communication System (PACS) has transformed the interactions between the Radiology Department and

the ICU. PACS has proved to be extremely beneficial (quality of images, radiation exposure) and has made accessing of radiological studies and results quick and easy.

Our paper has analysed the clinical value of routine chest radiography in the first 24 hours after cardiac surgery.

From all routine chest X-rays evaluated in our study, 7.28% resulted in one or more therapeutic interventions. Some of the therapeutic interventions performed might be considered minor or have little clinical importance. For some patients even minor interventions such as adjustment of the nasogastric tube or institution of chest physiotherapy could have important implications in management of their condition/illness. It is difficult to judge the level of intervention that would justify not performing routine chest radiographs in this population group.

One of the objectives of this study was to identify a subgroup of patients for whom performance of routine chest radiography is most useful. Inflammatory and infective conditions such as pulmonary tuberculosis, pulmonary hydatid disease, and HIV-related pulmonary diseases are prevalent in the Sub Saharan Africa. Pre-existing lung pathology has been identified as an important risk factor for post-operative pulmonary complications. We hypothesized that this population group would have more post-operative pulmonary complications that would justify the need for frequent routine post-operative chest radiography. Contrary to our hypothesis, the 17 patients identified as having had pulmonary tuberculosis previously, did not have any major or significant therapeutic interventions based on their routine chest X-rays. Therapeutic efficacy in this subgroup was actually 0%.

In our study, the pathological findings after cardiac surgery have a higher prevalence than that reported in other series. The diagnostic efficacy (like the therapeutic efficacy) was high: 38.47% (and 7.28% respectively). The

most likely explanation for this discrepancy is that we are dealing with a different population group and different disease spectrum.

This study did not attempt to analyse cost savings that would have occurred if routine chest radiographs had not been performed. The cost savings of not performing routine chest radiographs could be substantial. However, without being able to reliably place a value on the interventions performed during this study, it is difficult to calculate the additional costs of caring for patients that would have suffered bad outcomes because of missed significant radiological findings and missed opportunities to intervene timeously. For this population group bedside radiography has proven to be vital, often providing clinicians with information they would have otherwise missed.

This study also did not attempt to evaluate whether the use of routine chest radiography improves outcomes. That would have required a large number of participants and randomisation of patients (to receive or restrict chest radiography).

We believe that the type of analysis that has been performed in this study has highlighted the role of routine chest X-rays after cardiac surgery in a limited resources environment. The patients in this study had clinically significant decisions undertaken based on the results of the routine chest radiographs.

Performance of routine CXRs after admission to ICU can be justified if these CXRs are used as a reference point (baseline) if a patient's condition worsens during their stay in the ICU. "Negative" finding (i.e. not finding a specific abnormality) may be also an important sign for ICU clinicians. ICU clinicians may want to know whether their expectations are correct and whether they should continue treatment or not.

Rising health care costs and the need for evidence-based medicine and cost-effective practices, particularly in a resource-limited environment like South Africa, have led us to challenge routine protocol-driven chest

radiography in the intensive care unit. Also, advances in anaesthetic pharmacology and surgical technique, allow for fast tracking of the cardiac surgery patients. Given all these considerations, one might be inclined to agree with the authors of numerous articles that advocate abandoning of routine post-operative chest radiographs in post-cardiac surgery patients.

While a couple of articles advocate abandoning chest radiography, no study has evaluated the potential harm of missed findings in these patients that did not benefit from the routine chest radiography. No alternative imaging modality has proved to be as cheap, easy to use, and low in radiation dose or as quickly performed and easily interpreted, as bedside radiography.

9.2. Limitations

While our study is the only work done in Africa that analysed the clinical value of routine chest radiography following cardiac surgery, we recognize that it does have a number of limitations.

This study is limited by the assumption that all patients were evaluated clinically before reviewing their chest radiographs. The fact that discrepancy was noted between clinical examination and radiological findings supports this assumption.

Secondly, this is a single centre study (Groote Schuur Hospital, D22 Cardiothoracic ICU) and no comparison has been made with other diagnostic modalities (ultrasonography, tomography).

This being a retrospective study based on clinical records means that a number of assumptions were made, especially where clinical records were missing or hand writing was illegible. This immediately brings bias to the whole study.

The present results might not simply be translated/applied to other centres, not even in South Africa. Differences in staffing and managing of the units (intensivists, surgeons, anaesthetists, radiologists) as well as the patient population, and surgical techniques/procedures, might be of great influence upon the clinical value that routine bedside radiography has in a particular hospital/ICU.

9.3. Recommendations

Our work, this paper, can in the future form the basis of a prospective study on the utility of routine chest X-rays in the first 24 hours following cardiac surgery in the cardiothoracic intensive care unit at Groote Schuur Hospital.

Until then, based on the findings of this study, routine bedside chest radiography, despite its limitations, has a role to play in post-operative care of cardiac surgery patients. Recognition of the clinical and radiologic features of the various complications that may occur after cardiac surgery is imperative to achieve prompt and accurate diagnosis that may help reduce morbidity and mortality.