A Multicenter Retrospective audit on the treatment modalities of sternal sepsis: A 10-year review

Submitted by

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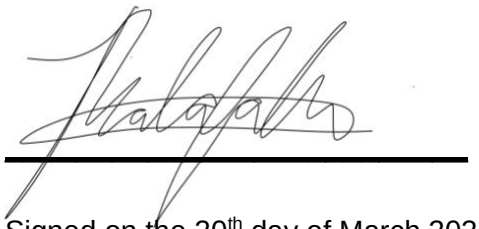
Declaration

I, Refilwe Palesa Mokgadi Phalafala, hereby declare that this medical research report submitted for Master of Medicine (Plastic and Reconstructive Surgery) titled “A Multicenter Retrospective Audit on the treatment modalities of sternal sepsis: A 10-year review” is my original work and has not in its entirety or in part been previously submitted to another university.



Signed on the 20th day of March 2024 in Charlotte Maxeke Johannesburg Academic Hospital

Dedication

This study is dedicated to my loving family & memory of my late grandfather, 'the Boys' and grandmother 'Rammkone' without your support, this would not have been possible.

Abstract

Background: Mediastinitis is a life-threatening complication, of a septic sternal wound. The key treatment is for early radical debridement and adequate reconstruction. The aim of this study was to perform a comparative review of the management modalities undertaken on patients with sternal sepsis from 2007–2017 at one public and two private surgical practices in Johannesburg, South Africa.

Methodology: The study was a retrospective series of 120 chronologically selected patients from three hospital units (40 from each unit): The Cardiothoracic Unit at Charlotte Maxeke Johannesburg Academic Hospital (CMJAH - public) and two private plastic surgery practices within Netcare Milpark Hospital (NMH). The patients were categorized into three groups: 1) Vacuum-Assisted Closure (VAC), 2) VAC and reconstruction (muscle flaps or alloplastic material) and 3) reconstruction alone (muscle flaps or alloplastic material).

Results: Of the120 patients, the median age, was 58yrs (19yrs – 89yrs). Hypertension was the most common comorbidity. Patients in NMH were more likely to undergo VAC dressing for a shorter period. Patients in NMH were more likely to be reconstructed with a flap (44%, n=35/78), of which the bilateral pectoralis major flaps (19%, n=43) was more frequent. Out of the 120 patients, 61% had one debridement and VAC therapy as a temporizing modality prior to reconstruction. CMJAH had a higher mean length of hospital stay of 41 days and re-do operations 27% (n=11/40) compared to NMH which had a mean hospital stay of 31 days and a re-do operations of 16% (n= 13/78). Plastic surgeons were more likely to be involved in initial debridement's in NMH 96% (n=32/33) compared to CMJAH with 3% (n= 1/33).

Conclusion: NMH, private hospital, demonstrated to have statistically significant better outcomes with a shorter hospital stay compared to its counterpart CMJAH, public

hospital, with regards to management of sternal sepsis. NMH, showed a shorter VAC dressing period to be an effective temporizing modality, however the most efficient management of, sternal sepsis, would be to involve a plastic surgeon early on for radical and fewer number of debridements, and early reconstruction. The bilateral pectoralis major flap was the option of choice in this study. The incidence of sternal sepsis from both hospitals was in keeping with international rates.

Keywords: Sternal sepsis, reconstruction, VAC therapy.

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I want to thank God, for guiding my path, shedding light every step of the way and fulfilling his promise. This journey wouldn't be possible without his grace, my faith and his unwavering support. *"God, is good all the time".*

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Abbreviations

AF:	Atrial Fibrillation
ANOVA:	Analysis of variance
AV:	Aortic Valve
CMJAH:	Charlotte Maxeke Johannesburg Academic Hospital
COPD:	Chronic Obstructive Pulmonary Disease
CVA:	Cerebral Vascular Accident
DVT:	Deep venous thrombosis
HF:	Heart failure
HPT:	Hypertension
HREC:	Human Research Ethical Committee
ICU:	Intensive Care Unit
IHD:	Ischaemic Heart Disease
IMA:	Internal mammary artery
LVEF:	Left Ventricular Ejection Fraction
MI:	Myocardial Infarction
MRSA:	Methicillin-Resistant Staphylococcus Aureus
NMH:	Netcare Milpark Hospital
NYHA:	New York Heart Association
OB:	Obesity
PE:	Pulmonary Embolism
PVD:	Peripheral Vascular Disease
Q:	Quartile
RF:	Renal failure
RVD:	Retroviral Disease
SBE:	Sub-acute Bacterial Endocarditis
S. aureus:	Staphylococcus aureus
SIRS:	Systemic Inflammatory Response Syndrome
SMK:	Smoking history
VAC:	Vacuum assisted closure

Chapter 1: Introduction

A septic sternal wound is a known complication post cardiac surgery, mediastinitis (the spread of an infection to the mediastinum) is a potentially life-threatening complication post cardiac surgery, with an incidence of 0.3%-5% [1]. The mortality has been previously recorded to be as high as 45% [2]. The morbidity of a patient with mediastinitis is costly due to lengthy hospital stays and operations. If done incorrectly it can recur with less favourable outcomes [3]. Arnold and Pairolero [4] pioneered diagnostic and treatment guidelines of septic sternal wounds, with the most severe form being mediastinitis, in the late 1970s and early 1980s, classifying them into three classes and the associated management thereof as follows and as shown in Figure 1.1.

Class 1 sternal wounds – Occurs a few days post sternotomy. The patients either have or have no sternal instability. There is no evidence of mediastinal suppuration, or osteomyelitis of the sternum. The management of patients with the following sternal wounds will include systemic antibiotics, surgical debridement, removal of previous sternal wires and pledgets followed by reclosure of the sternum with new wires [4,5].

Class 2 sternal wounds – Occurs a few weeks post sternotomy. Sternal instability is noted. Mediastinal suppuration is present with positive cultures and there is obvious communication between the sternum and mediastinum and osteomyelitis. Management here will include culture-directed antibiotics, debridement of the wound and pulse lavage dressing such as a Water Pik. Once no suppuration is noted, the closure of the wound with a muscle or omental flap is then indicated [4,5,6].

Class 3 sternal wounds – Occurs several weeks to several months post sternotomy. Sternal instability can be noted with a chronically draining sinus tract and positive cultures. Management of these wounds, includes computed tomography to detect retrosternal infection, multiple debridements is advantageous and reconstruction with flaps. Reconstruction is either with muscle or omental flaps. This will vary depending on the contour and outline of the defect [4,5,6].

El Oakley and Wright' modified the classification of deep sternal wound infection in 1996, where they depicted the risks and time of onset of symptoms [7].

Figure 1.1: Images of Class 1,2 and 3 sternal wounds respectively, from patients in CMJAH.

The exact pathophysiology of sternal sepsis is unknown however numerous factors can contribute to the development of sternal sepsis. Patients who are more prone to sternal sepsis post cardiac surgery are those with hypertension, smoking history, hyperlipidaemia, diabetes mellitus, renal failure, chronic lung disease, an ejection fraction ≤ 30%, steroid use, obesity and congestive heart failure. According to the New York Heart Association (NYHA) these patients would be classified as Class III and IV: patients with significant decrease in exercise intolerance with/without symptoms of heart failure at rest [8,9].

It has also been proven that patients who have bilateral internal mammary arteries harvested or re-do surgery, have a significant risk of sternal sepsis, due to poor wound healing from the decreased blood supply [10]. Intra-operative sterility is of utmost importance as wound contamination may occur [11]. Poor post-operative drainage of the field and re-exploration for bleeding pose a risk, which can be an unplanned event [11].

A prolonged duration of theatre time, including cardiopulmonary bypass time, also increases the risk of intraoperative wound contamination [12]. Prolonged mechanical ventilation and ICU stay of

more than 2 days are post-operative sequela, which leads to higher complication rates [13]. Furthermore, prolonged anaesthetic time has been proven time again to result in multiple pulmonary complications, including chest infections [14]. A compounding effect of blood loss resulting in the need for a transfusion, leading to shock and immense depression of the immune system has also been shown to increase wound infection rates[14].

Infection rates increase at a gradual inclination for every hour of surgery, in all types of surgical wounds [15]. Howland and colleagues noted that after 6 h of theatre time, there was a drastic inclination in complication rates such as renal, pulmonary, cardiovascular and wound complications [16]. In a study by Andenaes and colleagues, the authors looked at patients undergoing plastic surgery and their surgical site infection rate and noted that there was a three-fold increase in surgical site infection rate in surgeries lasting more than 2 hrs compared to that of less than 60 min [17].

Microbiology

Postsurgical mediastinitis is a deep infection involving retrosternal tissue and/or bone [16]. Positive cultures, including clinical signs and symptoms, are required for the diagnosis [19]. Multiple micro-organisms have been reported in sternal wounds [19]. Tammelin and colleagues noted that coagulase-negative staphylococcus was the most common pathogen in sternal sepsis, and lab results of patients with the highest rate of sternal dehiscence, produced coagulase-negative staphylococcus in their cultures [20].

Staphylococcus aureus (S. aureus) is amongst the common pathogens noted in sternal sepsis, followed by coagulase-negative staphylococcus. Many of these infections are from patient's own commensal bacteria. It has been shown that 20%-30% of the population carry *S. aureus* as part of their normal commensals, hence, the risk is increased three-fold in this group of patients [21].

Gram-negative bacteria cannot be ignored, most commonly *E. coli, Klebsiella* and *Enterobacter.* These will commonly be found from sources such as the lungs (i.e., pneumonia) and catheters [22]. Fungal infections post cardiac surgery are rare [23], however *Aspergillus flavus* is highly

suspected in patients with negative cultures, pleural effusions and wounds that are slowly progressive yet destructive [24].

In the paediatric population, patients with post-surgery wound sepsis portrayed a much lower mortality rate than in the adult population, due to their better wound healing properties and fewer risk factors and comorbidities [25]. Ghotaslou et al. established that, regardless of the number of risk factors a patient has for sternal wound sepsis, in the adult population the mortality due to gram-negative bacteria was higher than that of gram-positive bacteria [26].

The Vacuum-Assisted Closure (VAC) dressing

In 1997, the VAC system was first introduced in animals to prove the hypothesis that it would expedite wound healing [27]. This sub atmospheric pressure device proved that there was a greater rate of granulation formation, increased local blood flow, increase in bacterial clearance and decrease in local oedema compared to wounds dressed with saline [27].VAC dressing in sternal wound sepsis is crucial as a temporizing measure before flap cover [28]. It has been proven to reduce hospital stay, mortality rate and improve the prognosis of patients with *methicillin-resistant s. aureus (MRSA)* sternal wound sepsis [28].

A systematic approach for the placement of the VAC system is to cut a polyurethane foam/sponge in the shape of the geometry of the defect. This is placed in a debrided clean wound bed to prevent sharp edges from the sternum from penetrating the heart. Silicone tubes are sandwiched into the foam and are then connected to canisters. The wound was then sealed with a transparent polyurethane film and the device delivered a sub atmospheric pressure of 75–125 mmHg, which fast tracks healing [29].

Indications for reconstructive muscle flaps, for sternal wounds post cardiac surgery, are wounds with sternal bone loss and/or soft tissue loss. The workhorse muscle flap for sternal wound cover is the pedicled pectoralis major flap. Other musculocutaneous flaps that can be performed are the rectus abdominis and latissimus dorsi flap. Visceral flaps such as omental flaps have also been well described for sternal cover [30].

Figure 1.2: VAC dressing placed on sternum of patients in CMJAH.

The Pectoralis Major Flap

The pectoralis major flap is considered a workhorse muscular flap for sternal defects [31]. This flap can be used as an advancement flap or a turnover flap. Care must be taken when performing the turnover flap as it's based on the internal mammary arteries (IMA), intraoperative assessment of these arteries is to be done to assess if the arteries have been harvested or damaged in previous cardiac surgeries. It is reliable, versatile in covering all size defects and can be used as a musculocutaneous or even an osteomyocutaneous flap [31]. The disadvantage however is the inability of the flap to cover wounds over the lower third of the sternum, xiphoid and epigastrium [32].

The Latissimus Dorsi Flap

The upper two-thirds of the sternum can be covered adequately with a latissimus dorsi flap [33]. The advantage is that it preserves collateral blood supply to the sternum, however there is a high rate of seroma and haematoma formation [33]. Raising the flap is labour intensive, as the patient is in the lateral decubitus position and intraoperative re-positioning is required to supine for flap insertion [34].

The Rectus Abdominis Flap

This flap is an excellent option where internal mammary arteries have been harvested. It has good cover over the anterior, lower third sternal and anterolateral defects. It can be based on the superior epigastric arteries, deep inferior epigastric arteries and the eight intercostal arteries, this will allow for the flap to be advanced into the sternum and no intraoperative position change is required [35].

The Omental Flap

This transposition omental flap is a well-vascularized amorphous flap and has been used when muscle flaps have failed. The advantage is that it is a robust, long pedicled flap, which has good immunological properties. The disadvantage is the possibility of fat necrosis, the laparotomy midline incision and the need for a skin graft above the omental flap [36].

Microsurgical Flaps

These are perforator and muscle flaps for severe defects and failed attempts where other donor areas are not available [37].

1.1 Study Aim and rationale

The aim of this local retrospective study was to perform a comparative review of the management modalities undertaken on patients with sternal wound sepsis from 2007–2017. The study involved three centres namely, the Department of Cardio-thoracic Surgery at Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) and two Plastic Surgery private practices within Netcare Milpark Hospital (NMH), all located in Johannesburg, South Africa.

This study reviewed VAC dressing as a solitary modality of treatment compared to the same procedure being used as a temporizing measure before reconstruction. The study reviewed patients for whom reconstruction with muscle flaps was the sole treatment modality. Management modalities, concerning sternal wound sepsis, were extrapolated from these results. Findings from this study will provide information on the use of VAC dressing as a primary

modality treatment or as a temporizing measure prior muscle or omental flap reconstruction, and how it has revolutionised outcomes and complications thereof.

1.2 Study objectives

- To compare the patients who had VAC dressing, VAC dressing and flap reconstruction and the patients who had flap reconstruction alone concerning
    - Length of hospital stay, including ICU ventilation.
    - Which reconstruction flap was performed and if a re-do operation was performed?
    - Comorbidities associated with length of hospital stay.
- To comparatively review the incidence of sternal sepsis among the three centres

Chapter 2: Methodology

2.1 Methods

Ethical clearance for this study was obtained from the University of the Witwatersrand's Human Research Ethics Committee (HREC), with medical clearance certificate number M190632. The study was a retrospective multicentre case record analysis at three multi-disciplinary hospitals made up of cardiothoracic surgeons, plastic surgeons and cardiologists. These were the Department of Cardio-thoracic Surgery at Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) and two different Plastic Surgery private practices within Netcare Milpark Hospital (NMH).

CMJAH is a public hospital situated in Parktown, Johannesburg, Gauteng Province, South Africa. It is a quaternary hospital with specialised units. NMH is a private hospital also situated in Parktown. It is a level 1 accredited trauma unit with a specialized burn centre. These two hospitals are two-out-of-thirty-nine hospitals that serve the five million six hundred thousand plus people living in Johannesburg. This number excludes patients referred from other provinces and countries.

For the purposes of this study, all patients who had sternal sepsis, post cardiac surgery, from the year January 2007 to December 2017 were included. The inclusion of multiple hospitals allowed for the inclusion of patients from a range of various socio-economic backgrounds.

The first patient contact is usually from the cardiologists, who will refer the patients to these specialized units at CMJAH and NMH Cardiothoracic Units. The cardiothoracic surgeons undertake management plans. When mediastinitis is reported, plastic surgeons are usually consulted where flap cover is indicated.

Information regarding the patient's age, comorbidities, cardiac operation/s (including reconstructive operations), how the wound was managed, whether VAC dressing was used and if reconstructive flap cover was done, were documented from their medical records. All information was recorded on a data collection sheet (see Appendix A). Male and female adult patients who were 18 years and above were included in the study. The patients were

grouped into three broad categories: 1) Vacuum-Assisted Closure (VAC), 2) VAC and reconstruction (muscle flaps or alloplastic material) and 3) reconstruction alone (muscle flaps or alloplastic material). Patients who had received alternative therapy, such as sternal transplantation, were excluded from the study.

2.2 Data Analysis

All statistical information was recorded on a data collection sheet (Appendix A). All the information was computerised in Microsoft Excel (Microsoft Excel 2011 for Mac, Microsoft Corporation, Redmond). Data analysis was performed with the assistance of the Health Science Research Office (Biostatistics Unit). The results were reported as frequencies, mean ± standard deviation, median and range. Fisher exact and Chi-square tests were performed, for categorical variables (re-do operations, comorbidities and gender). An analysis of variance (ANOVA) test was used for continuous variables in the three comparative groups and regression analysis was used for comorbidities associated with length of stay on Statistical Analysis System (SAS) software (SAS Institute, North Carolina). A *p-value* <0.05 was regarded as statistically significant.

Chapter 3: Results

Of the 120 patients, 40 were chronologically selected from each unit (CMJAH and the two-plastic surgery private practices in NMH) and included in the study according to the study inclusion criteria (Patients post cardiac surgery, who had sternal sepsis, from both genders and are 18 years or above). This was followed by analysis of the demographic characteristics, prognosis in terms of hospital stay and re-do operations based on information from respective patient hospital files. Reconstructive options performed were analysed, to see their impact on prognosis as well as comorbidities associated with sternal sepsis and how influenced outcomes (length of hospital stay) are affected.

3.1 Patients' Characteristics

Table 3.1, below, shows the total number of patients and their characteristics with sternal wound sepsis from the two hospitals, CMJAH and the two NMH Plastic Surgery Units listed as NMH. The age distribution among the hospitals was a minimum age of 19 years while the maximum was 89 years. Overall, the ages were negatively skewed-towards the older age groups (above 50 years). In NMH the median age was 58 years (19-84 years) and in CMJAH the median age was 62 years (19-89 years). 40 patients, from each unit, were selected chronologically from the start date January 2007 till December 2017.

Notably, as shown in Table 3.1, the number of comorbidities per patient, differed by site. NMH patients were less likely to have multiple comorbidities compared to CMJAH (27.5% vs 38.75%). Patients could have one, two or multiple (noted as 3 or more) comorbidities, the total number of patients with comorbidities in CMJAH was 90% (n=36/40) and in NMH was 87.5% (n=70/80), and the remainder of the patients had no comorbidities. There were 40 different comorbidities that were documented in the study however the most prevalent comorbidity was hypertension (45%, n=54), other comorbidities such as epilepsy, hypothyroidism, atrial fibrillation, infective endocarditis and more are some of the other comorbidities that were the least prevalent in this study .

Exclusion criteria were patients under the age of 18 years old, and any patient that underwent sternal transplantation.

Table 3.1: Patients' Characteristics

	Hospital	**No.**	**Percent %**
Site	*CMJAH*	40	33.3
	NMH	80	66.6
Gender	*Female*	41	34.1
	Male	79	65.8
Age	*<20 years*	3	2.5
	21–29 years	12	10.0
	31–40 years	19	15.8
	41–49 years	28	23.3
	50+ years	58	48.3

Comorbidity (no.)			
(CMJAH)	*Multiple (≥3)*	*11*	*27.5*
	One	*14*	*35*
	Two	*11*	*27.5*
	Total	*36*	*90*
(NMH)	*Multiple (≥3)*	*31*	*38.7*
	One	*20*	*25*
	Two	*19*	*23.7*
	Total	*70*	*87.5*

	CMJAH(no.)	*%*	*NMH*	*%*	*Total(no.)*	*Total(%)*
Comorbidity (types)						
Hypertension	*17*	*42.5*	*37*	*46.2*	*54*	*45*
Smoking history	*5*	*12.5*	*31*	*38.7*	*36*	*30*
Hypercholesterolaemia	*12*	*30*	*20*	*25*	*32*	*27*
Diabetes Mellitus	*12*	*30*	*19*	*23.7*	*31*	*25*
Obesity	*5*	*12.5*	*13*	*16.2*	*18*	*15*

The association in wound size in the two hospitals was noted. There were no pronounced differences in wound size in CMJAH and NMH.

3.2 Vacuum-Assisted Closure (VAC) used for closure of wound

In total, there were 50 patients who had VAC dressing (41.6%) out of the 120 patients from the three units. The Vacuum-Assisted Closure dressing was used for a minimum of 2 days and the maximum was 20 days. The average number of days for VAC dressing was five days for both hospitals while CMJAH's average number of days was eight days compared to NMH's four days. VAC dressing was done in four out of ten (41%, n=50/120) of all the patients. Those who had VAC dressing were more likely to be from NMH (44.3%, n=35/79) compared to CMJAH (35%, n=14/40). These differences across the hospitals were not statistically significant ($p>0.05$).

3.3 VAC and reconstruction (either with muscle flaps or alloplastic material)

VAC dressing was used as a temporizing measure, in between debridements, prior to final reconstruction. Of the 120 patients, 61% (n=73/120) of the patients had one debridement before reconstruction, followed by 16% (n=19/120) who had two debridements while 13.6% (n=16/120) had three or more debridement's before reconstruction. The maximum number of debridements was 10. VAC dressing was used as a temporizing measure prior to final reconstruction. Within the multiple debridement group in totality which was, 39% (n=47/120), CMJAH had more patients who underwent multiple debridements 57% n=27/47 compared to 42% in NMH n=20/47, Pearson $Chi^2(6) = 25.31$, $p<0.001$, which is statistically significant. No patients in the study underwent alloplastic reconstruction.

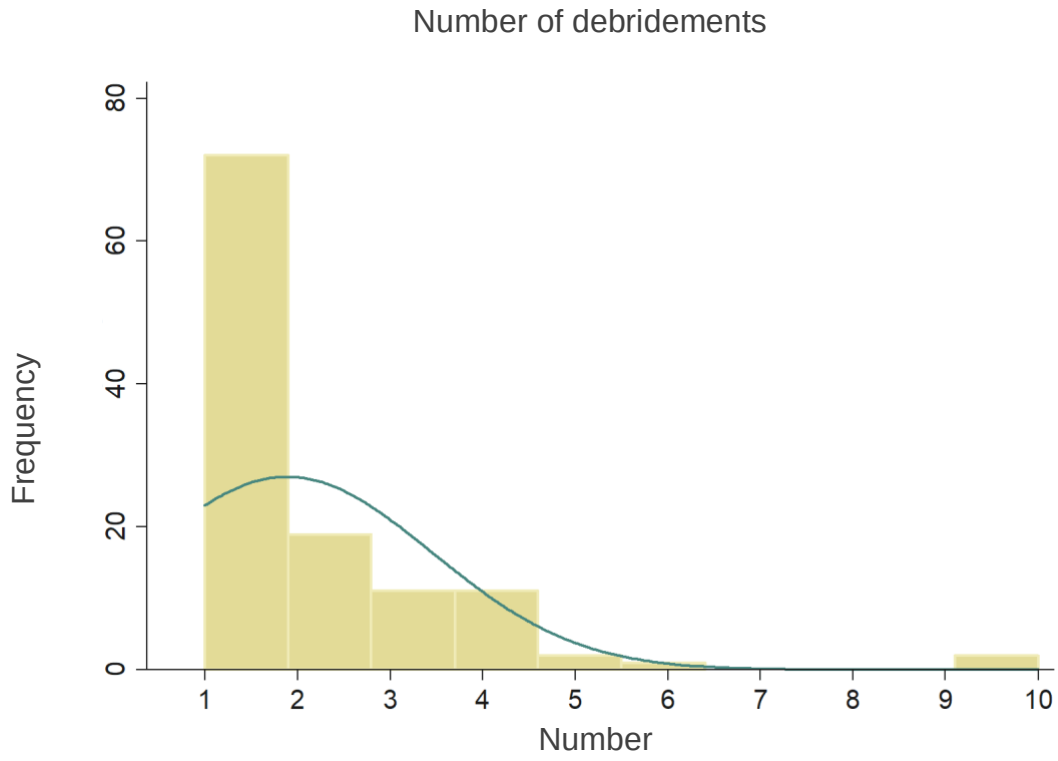

Figure 3.1: The number of debridements prior to reconstruction

3.4 Plastic Surgery involvement

Patients in NMH were much more likely to have a plastic surgeon involved in their initial debridement: 40.5% (n=32/79), compared to CMJAH 2.5% (n=1/40). The role of the plastic surgeon is for an adequate radical debridement and to ascertain that future soft tissue flaps are not jeopardized. Pearson Chi^2 (1) =19.13, $p<0.001$ which is statistically significant.

3.5 Reconstruction

The frequency of reconstruction only, which could either be with muscle flaps or alloplastic material, was assessed. Patients who did not undergo reconstruction had secondary closure with various methods as stated below. Table 3.2 suggests that patients from CMJAH were more likely not to have undergone reconstruction with flaps, results significant at 5% level (Pearson Chi^2 (1) = 5.659 Pr = 0.017). The various types of reconstruction techniques used are also shown in

Table 3.2, this could be a musculocutaneous flap, a fasciocutaneous flap, or skin graft. Of the 44 flaps performed at both hospitals, the bilateral pectoralis major flap was most frequently done at 43.2% (n=19/44). Flaps are used to provide adequate tissue coverage to obliterate dead space and to protect underlying viscera. Of the 76 patients who did not undergo reconstruction in either hospital, however had secondary closure, rewiring of the sternum accounted for the majority at 55.8% (n=42/76). Rewiring of the sternum occurs when the integrity of the sternum is healthy and viable post debridement, such that wire sutures can still pass through the sternum to approximate the bone. Re-suturing of the skin accounted for the second most prevalent secondary closure method at 38.9% (n=30/76), and this occurs when there is a superficial wound post debridement, and the integrity of the bone beneath is intact, and there is adequate soft tissue to close the defect . The various forms of secondary closure are shown in Table 3.2.

Table 3.2: Flap usage for reconstruction in the various hospitals and the various reconstruction techniques used.

	CMJAH		NMH		Total	
Reconstruction	*Freq*	*Perc %*	*Freq*	*Perc %*	*Freq*	*Perc %*
No	32	78	44	55.7	76	63.3
Yes	9	22	35	44.3	44	36.7
Total	41	100.0	79	100.0	120	100.0
Reconstruction Technique	Frequency			%		
1)Bilateral Pectoralis Major Flap	19			43.1		
2)Rectus Abdominus Muscle Flap	10			22.7		
3)Rotational Flap- fasciocutaneous flap	9			20.4		
4)Unilateral Pectoralis Major Flap	5			11.3		
5)Skin graft (post VAC therapy)	1			2.2		
Total	**44**			**100**		
Types of secondary closure	Frequency			%		
Re-suturing of skin	30			38.9		
Re-wiring of the sternum	42			55.8		
Titanium Sternal Plating	4			5.1		
Total	**76**			**100**		

3.6 Frequency of re-do operations

Re-do operations were more likely to occur at CMJAH, of the 24 patients who underwent re-do operations, 30.9% (n=13/43) were from CMJAH compared to 14.2% (n=11/77) from NMH. All results were statistically significant at 5% level (Pearson $Chi^2(1) = 5.6592$ Pr = 0.017). However the number of re-do operations performed on a patient were not statically significant (p>0.05).

The most prevalent re-do operation that was performed across both hospitals was rewiring of the sternum, n=8/24 33.4% , which was followed by haematoma evacuation at n=4/24 16.6%.

Table 3.3: Frequency of re-do operations post reconstruction or secondary closure, and the amount of re-do operations

	CMJAH		**NMH**		**Total**	
	Freq	Perc %	Freq	Perc %	Freq	Perc %
Re-do theatre operations						
No	30	69.7	66	85.7	96	80
Yes	**13**	**30.2**	**11**	**14.2**	**24**	**20**
Total	43	100	77	100	120	100
If yes, the number of re-do operations done on a patient						
1	4	40	9	69.2	13	56.5
2	4	40	4	30.7	8	34.7
3	2	20	0	-	2	8.7
Total	10	100	13	100	24	100

3.7 Length of hospital stay, including ICU ventilation

The number of days stayed in hospital varied between patients, from a minimum of seven days to a maximum of 107 days for all patients as shown in Figure 3.2.

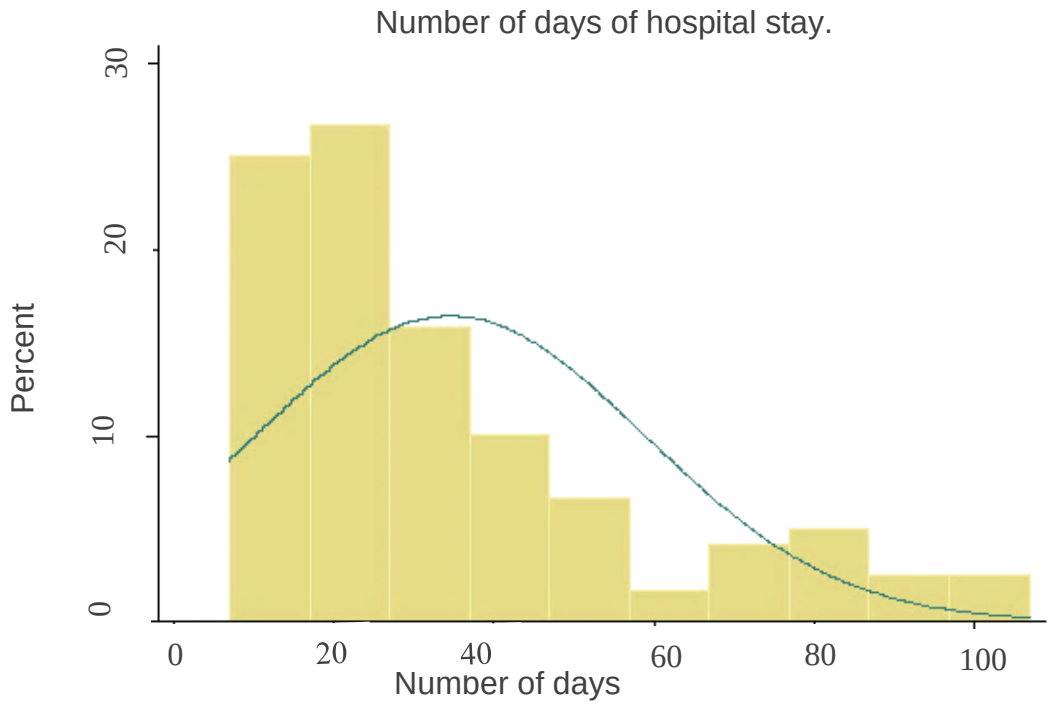

Figure 3.2: Distribution of length of hospital stay.

According to the results, CMJAH had a relatively higher average number of days spent in hospital at 41 ±21.25 days, ranging from 7–92 days compared to NMH 31.34 ±24.25 days with a range of 7–107 days.

The data on days stayed in both hospitals were recorded, and more than half of the patients stayed in the hospital for 7–30 days (58.3%). A quarter of them (26.7%) stayed in the hospital for 30–60 days, while a tenth stayed more than two months.

The mortality from both hospitals combined was 13.2% (n=16/120) with no significant differences between CMJAH which recoded 15% (n=6) vs NMH at 11.3% (n=9). The results showed that patients who stayed in the hospital for two months or more were more likely to die, although weak evidence as the results are significant at 10% level (p>0.1) (Pearson chi2(56) = 68.79 Pr = 0.117).

Table 3.4 shows that there were significant differences (Pearson Chi²(4) = 11.36 Pr = 0.023) among those who had stayed longer in hospital (31–60 days) and the number of comorbidities. Comorbidities were broken up into patients who had one, two, or multiple (3 or more) comorbidities. The total number of patients with comorbidities in CMJAH was 90% (n=36/40) and in NMH was 87.5% (n=70/80), and the remainder of the patients (n=14/120) had no comorbidities. Those who had one comorbidity were more likely to have a shorter hospital stay (30 days and less) compared to those with multiple comorbidities (n=21/34, 33.8% vs. n=28/42, 45.1%). Those with a single comorbidity were less likely to stay 60+ days (6.2%, n=1 vs 56.2%, n=6 for those with multiple).

Table 3.4: Comorbidities associated with length of stay for all hospitals.

Length of stay	**Multiple**		**One**		**Two**		**Total**	
	Freq	Perc %	Freq	Perc %	Freq	Perc %	Freq	Perc%
30 days and less	28	45.1	21	33.8	13	20.9	62	58.4
31–60 days	8	28.5	12	42.8	8	28.5	28	26.4
60+ days	6	56.2	1	6.2	9	56.2	16	15
Total	42	39.6	34	32.0	30	28.3	106	100

3.8 Incidence of Sternal sepsis

Over the 10 year period during which the incidence of sternal sepsis was reviewed in the CMJAH (2007-2017), a total of 10 800 patients had a surgical procedure, with a total of 584 (5.4%) documented as sternal sepsis patients. In NMH over a 10 year span (2007-2017) a total of 9345 patients had a surgical procedure, with a documented 262 (2.8%) patients with sternal sepsis.

3.9 Pairwise Correlation analysis

A pairwise correlation was performed to determine positive or negative correlations between various parameters and the associations are shown in Table 3.5. The correlation, is in effect size and can verbally describe the strength of the correlation (Cooper and Schnindler, 2006). The strength can be classified as 00–0.19 “very weak”, 0.20–0.39 “weak”, 0.40–0.59 “moderate”, 0.60–0.79 “strong”, and 0.80–1.0 “compelling”. Table 3.5 shows the strengths of the associations.

Table 3.5: Correlation between Comorbidities (Comorb) and length of hospital stay.

Correlations									
	Comorbidities	Hospital	Days in hospital	Died	Days with VAC	Number of Debridements	VAC Dressing (y/n)	Plastic surgeon present	Reconstructive Flaps used
Comorbidities	1	-0.099	0.200*	0.087	0.104	0.199*	0.039	0.159	0.164
Hospital	-0.099	1	-0.259**	-0.053	-0.565**	-0.408**	0.089	0.401**	0.219*
Days in hospital	0.200*	-0.259**	1	0.131	0.447**	0.413**	0.162	0.207*	0.172
Died	0.087	-0.053	0.131	1	0.094	0.137	-0.027	-0.132	-0.098
Days with VAC	0.104	-0.565**	0.447**	0.094	1	0.523**	.c	-0.089	0.000
Number of Debridements	0.199*	-0.408**	0.413**	0.137	0.523**	1	0.212*	0.009	0.138
VAC dressing (y/n)	0.039	0.089	0.162	-0.027	.c	0.212*	1	0.248**	0.257**
Plastic surgeon present	0.159	0.401**	0.207*	-0.132	-0.089	0.009	0.248**	1	0.809**
Reconstructive Flaps used	0.164	0.219*	0.172	-0.098	0.000	0.138	0.257**	0.809**	1
Re-do operation	0.160	-0.127	0.312*	0.341*	0.360*	0.276*	0.081	0.013	0.168

*Correlation is significant at the 0.05 level
**Correlation is significant at the 0.01 level
c. Cannot be computed because at least one of the variables is constant.

A positive statistically weakly significant correlation (r=0.199, p<0.05) between *the length of hospital stay* and comorbidity was noted. The results show that for every unit increase in the length of stay in hospital, there was a unit increase for comorbidity occurred. Those who had multiple comorbidities were more likely to stay longer in hospital compared with those who had one comorbidity.

The number of debridements of the wound had a positive statistically significant correlation, although weak at (r=0.198, p<0.05) with the comorbidity of disease associated with wounds. The results show that a unit increase in the debridement number was likely to increase as comorbidity increased. Those who had multiple comorbidities were more likely to experience multiple *debridement*s of the wound compared with those who had one comorbidity.

A weak association between patients undergoing surgery and length of stay in hospital was noted (r=0.219, p<0.05). Undergoing surgery increases the risk of staying in hospital for more than 30 days. Those who had reconstructive surgery (r=0.401) with a flap (r=0.219) were more likely to be patients from NMH. A moderate association (r=0.446) was noted where the more days a patient spent on the vacuum-assisted closure dressing, the longer they stayed in the hospital. A increase in the number of debridements was more likely to increase the length of stay in the hospital (r=0.413).

Taking the patient back to theatre, for a re-do operation post reconstruction, was associated with an increase in, the length of hospital stay (r=0.312), increase in mortality (r=0.341), increase number of days VAC dressing was used (r=0.360) and increased the patients' number for multiple debridements (r=0.276).

3.10 Regression Analysis: Risk factors of sternal sepsis

It's important to understand the predictors of sternal sepsis. As shown above, and from other reports, comorbidities correlate positively with sternal sepsis and length of stay. Patients with more comorbidities were more likely to have a longer hospital stay. In this study, hypertension, smoking, hypercholesterolaemia, diabetes mellitus and obesity were the most prevalent

comorbidities. To determine the effect of other variables such as gender on the length of stay, a multivariate regression analysis was performed, as depicted in Table 3.6 below.

Table 3.6: Multivariate Regression Showing Factors affecting length of hospital stay.

Length of stay (30 days and below)	**Coef.**	**Std. Err.**	**T**	**P>t**	**95% Conf**	**Interval**
Comorbidity	**0.020**	0.08	0.24	0.81	- 0.1	0.187
VAC Dress	**0.061**	0.13	0.45	0.651	- 0.2	0.329
Debridement-Y/N	**0.793**	0.26	3	0.003	0.2	1.317
Reconstruction	**- 0.365**	0.23	-1.57	0.121	- 0.8	0.098
Re-do operation	**0.426**	0.18	2.39	0.019	0.07	0.780
Number Debridement	**0.310**	0.17	1.86	0.067	- 0.0	0.642
Died	**0.190**	0.21	0.9	0.372	- 0.2	0.610
NMH	**- 0.439**	0.18	-2.5	0.014	- 0.7	- 0.091
Age> 50	**0.007**	0.16	0.04	0.966	- 0.3	0.319

The need for re-do operations increased hospital length stay: There was a relationship between re-do operations and length of hospital stay. Patients returned to the theatre post reconstruction, were more likely to stay in hospital for more than 30 days ($\beta=0.426$, $p<0.05$).

These results show that if a patient underwent a reconstruction procedure, they were bound to stay longer in hospital compared with those who did not undergo reconstruction.

The higher the number of debridements, the longer the hospital length of stay: There was a moderate relationship between the number of debridement's prior reconstruction and the hospital length of stay ($\beta=0.310$, $p<0.1$), results are significant at 10% level. Debridement in this cohort increased the number of days a patient stayed in the hospital (30–90 days), compared with those who did not undergo debridement (stayed 30 days or less).

*A shorter hospital stay was observed at NMH***:** There was a moderate negative relationship between NMH and length of hospital stay, ($\beta=-0.439$, $p<0.05$). These results show that NMH was less likely to have patients stay longer in the hospital, compared with CMJAH, where patients were more likely to stay longer.

Parameters with no significant differences

There was no relationship between comorbidity, VAC dressing, reconstruction, death, age group, gender and length of hospital stay.

Chapter 4: Discussion

The main reason for doing this study was to find an optimal management option for sternal sepsis in South Africa, regardless of public or private sector hospitals. The purpose of different trends in treatment modalities is to reduce morbidity, reduce hospital stay and have a good prognostic outcome. There are multiple similarities in statistics in international literature, however, they're a few differences.

Sternal wound sepsis is a common complication in post median sternotomy. The incidence of sternal sepsis internationally is between 0.3-5%[1]. This study's sternal sepsis incidence, is in keeping with international percentages with CMJAH at 5.4% and NMH at 2.8%. History has provided various modalities for managing sternal wound sepsis [1,2]. This study assessed three groups of treatment modalities: VAC therapy alone, VAC therapy with reconstruction and reconstruction alone.

Even though sternal sepsis can be further subdivided into superficial and deep this study did not investigate the various degrees of sepsis, but it rather focused on the treatment modalities regardless the degree of sepsis. If left untreated, these infections spread rapidly, causing mediastinitis[4,5]. In this study, the overall mortality for sternal sepsis was 13%, and is in keeping with international statistics [9,10].

Patients who are more prone to sternal sepsis post-cardiac surgery are patients with hypertension, smoking history, advanced age, obesity and diabetes [10]. Hypertension was the most prevalent comorbidity in this study (45%), the second most prevalent comorbidity was smoking (30%). Many of these comorbidities were modifiable. Obese patients (15% of the patients in the study) have been proven to be 2.1 times more likely to have sternal wound infections [10]. Patients who have one comorbidity are less likely to stay longer in hospital compared with those with multiple comorbidities, and patients with one comorbidity were much less likely to stay 60+ days compared to those with multiple comorbidities. (2.8% vs 44.3%).

VAC dressing has been proven repeatedly in terms of wound healing to decrease bacterial load, oedema, promote granulation tissue and reduce the wound diameter size [27]. Forty-one patients [18%] had VAC dressings, with most of these patients from NMH, private hospital, compared to CMJAH, public hospital, (44% vs 35%). VAC dressing has been proven to decrease the hospital stay and reduce mortality [27,28]. This study supports the use of VAC dressing to reduce the length of stay in hospital. This study also deduced that NMH, private hospital, comparatively speaking to CMJAH, public hospital, was more likely to have a plastic surgeon present at their initial debridement (40.5% vs 2.5%) and muscle flap procedures used for reconstruction. These factors are all evident in that it decreased patient length of stay in the hospital.

VAC dressing, not only decreases the time before flap closure, but it also optimises the wound bed by ensuring negative bacterial cultures [30]. The mean number of days for the VAC dressing was five days, this decreases the need to change dressings daily. This therapy has been proven to be an effective temporizing tool and solitary measure, of sternal reconstruction, especially where the patients are unfit or refuse surgical treatment.

Patients in NMH (44.9%) were twice as likely to have reconstruction flaps done compared to those in CMJAH (22.5%). Immediate reconstruction has been mandated to have the best prognostic outcomes. The use of various musculocutaneous flaps for reconstruction has been described as the optimum choice for post sternal sepsis defects [30,31]. The study corresponds to numerous international studies, in that the workhorse flaps for sternal reconstruction is the pectoralis major flap with it being 54% of the flaps done in this study, 43% being bilateral and 11% unilateral [31,32].

The pectoralis major flap is beneficial for obliterating sternal defects with well vascularised tissue [34,36]. However, it poses its challenges in covering the distal third of the sternum. The unilateral pectoralis major muscle flap can be used as a turnover flap or an advancement flap. In this study five patients underwent unilateral pectoralis major flap reconstruction [31,32]. The use of the turnover flap is based on the internal mammary perforators and its release from its insertion, the

clavicle and lateral lip of the bicipital groove of the humerus, and then turned on itself. The advancement flap is released from the origin, the sternum, and advanced medially. The flap use is based on the thoracoacromial artery [34,36].

In the case of large defects, bilateral pectoralis major muscle flaps may be used. Among the patients who underwent reconstruction (43%), the vast majority, underwent bilateral pectoralis major flap procedures. This could be due to the nature of the cardiac surgery or the initial radical debridement, the IMA perforators are damaged, hence the pectoralis major muscle flap maintains viability on the dominant blood supplying the pectoral branch of the thoracoacromial artery.

There are numerous advantages of using the workhorse pectoralis major flap. There is decreased morbidity in shoulder mobility (in the case of bilateral pectoralis major flap), sufficient chest stability, no respiratory impairment, a relatively avascular plane when dissecting, early wound closure, excellent cosmetic outcome, and good long-term results.

The choice of flap depends mainly on the size and depth of the sternal defect, which major perforators have been sacrificed (i.e. the IMA perforators) and the experience of the surgeon.

Secondary closure of the sternum either by re-suturing, re-wiring, or titanium plating of the sternum was done in 76 of the 120 patients. This shows that the conventional re-wiring of the sternum is still widely preferred by cardiothoracic surgeons. However, it’s been statistically proven that there is a four times higher mortality rate in patients who have had their sternum re-wired than in patients who underwent flap cover [40]. Bringing in a well vascularized muscle flap has been proven to be a first-line surgical approach [36,37,40-42].

In recent times, new alloplastic treatment modalities have emerged, such as the three-dimensional printed implants, which are said to be technically feasible with a great cosmetic result. However, the drawback of some of the latest alloplastic prosthesis is their availability in certain countries and the cost [38].

Secondary closure can only be performed once the infective process has ceased and a flap closure can only then be performed [41]. In this study, although all patients underwent the necessary steps for the current treatment modality of sternal wound sepsis: radical wound debridement, removal of de-vitalised bone and reconstruction, only a quarter (27.5%) of the patients had a plastic surgeon involved in their initial debridement, with 97% of these patients from NMH private hospital. Singh et al. also indicated that patients with deep sternal wound infections who were referred to a plastic surgeon showed a statistically significant decrease in mortality, ventilator dependence, and tracheostomy placement compared, to patients who were managed by cardiac surgeons [44].

In this study 71.6% of the patients were above the age of 50 years. The median age in the CMJAH patients was 62 years and in NMH patients is 58 years. There was a positive correlation between advanced age, specifically 70 years old and above, and mortality. Not only has it been proven that postoperative systemic inflammatory response syndrome (SIRS) occurs frequently in post cardiac surgery, but old age is a risk factor for SIRS and has an increased mortality risk [43].This study had a mortality rate of 13%. Contributory factors to mortality are not only age, but also length of hospital stay, hospital-acquired infections, re-do operations and the complexity of the diagnosis. It has been proven that patients were more likely to stay longer in hospital in CMJAH than in NMH. This correlates directly with the fact that the patients from NMH were more likely to undergo flap cover, which significantly reduces the length of hospital stay.

It is crucial for medical practitioners to understand and grasp the predisposing risk factors for sternal wound sepsis, to prevent complications and decrease length of stay in the hospital. Guidelines should be in place for sternal sepsis to reduce the incidence within hospitals and to have a better prognosis for patients. VAC therapy has revolutionized the approach to sternal wound management in a positive light and the role of the plastic surgeon is important in the initial debridement and early flap cover. Timing is of the utmost importance, this key component in the sternal reconstruction has reduced mortality and morbidity, shown in various studies and this study concurs with the published data.

Limitations

The degree of sternal sepsis was not specified, it was taken as a whole component, which could have influenced management, where flaps would be used for more moderate to severe sepsis. Being retrospective, the study relied on the accuracy of hospital records for the included patients.

Conclusion

NMH, private hospital, demonstrated to have statistically significant better outcomes with a shorter hospital stay compared to its counterpart CMJAH, public hospital, with regards to management of sternal sepsis. NMH, showed a shorter VAC dressing period to be an effective temporizing modality, however, the most efficient management of sternal sepsis, would be to involve a plastic surgeon early on for radical and fewer number of debridements, and early reconstruction. The bilateral pectoralis major flap was the option of choice in this study. These key components in sternal reconstruction has reduced mortality and morbidity. Overall the study's incidence of sternal sepsis from both hospitals was in keeping with international rates.

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Appendix A – Data Collection Sheet

Study number: _____

Hospital: _____ (CMJAH/NMH)

Age: _____

Female or Male: _____

Comorbidities:

	Yes	No	Unspecified
Hypertension			
Diabetes Mellitus			
Smoking			
Hypercholesterolemia			
Chronic Obstructive Pulmonary Disease			
Obesity			
Renal failure			
Heart Failure			
Steroid use			
BMI: (≥ 30)			
The left ventricular ejection fraction (LVEF) ≤30			
Other: Specify			

Management

Wound

Wound size (cm): _____

(If unspecified, note – unspecified)

VAC therapy used (Yes/no)? _____

If yes, duration of the therapy (days)? _____

Debridement's

Amount prior reconstruction: _____

Was a plastic surgeon involved in debridement's (Yes/no)?

_____

Reconstruction

Reconstructive Flaps used (yes/no): _____

If yes, which Flap was used: _____

Complications post Flap, if any: _____

Bone reconstruction (yes/no): _____

If yes, was an autologous or alloplastic material used: _____

Duration of hospital stays post Flap: _____

Re-do operation

Was the patient taken back to the theatre post reconstruction (Yes/no)? _____

How many re-do operations were done for these patients? _____

If yes, what was done? _____

Hospital stay

Total number of days in hospital? _____

Appendix B – Ethics clearance certificate

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

R14/49 Dr Refilwe Palesa Mokgadi Phalafala

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M190632

NAME: (Principal Investigator)	Dr Refilwe Palesa Mokgadi Phalafala
DEPARTMENT:	Plastic and Reconstructive Surgery Charlotte Maxeke Johannesburg Academic Hospital Netcare Milpark Hospital
PROJECT TITLE:	A Multicenter retrospective audit of the treatment modalities of sternal sepsis: A 10-year review
DATE CONSIDERED:	28/06/2019
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Prof Ndobe
APPROVED BY:	Dr. CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	01/07/2019

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary on the Third Floor, Faculty of Health Sciences, Phillip Tobias Building, 29 Princess of Wales Terrace, Parktown, 2193, University of the Witwatersrand. I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. In this case, the study was initially reviewed in **June** and will therefore be due in the month of **June** each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix C: Approved protocol

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Private Bag 3 Wits, 2050
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Reference: Mrs Sandra Benn
E-mail: sandra.benn@wits.ac.za

18 July 2019
Person No: 301417
PAG

Dr RPM Phalafala
123 Killarney Park
5th Street
Killarney
2193
South Africa

Dear Dr Refilwe Phalafala

Master of Medicine in Plastic and Reconstructive Surgery: Approval of Title

We have pleasure in advising that your proposal entitled *A multicentre retrospective audit of the treatment modalities of sternal sepsis:A 10-year review.* has been approved. Please note that any amendments to this title have to be endorsed by the Faculty's higher degrees committee and formally approved.

Yours sincerely

Mrs Sandra Benn
Faculty Registrar
Faculty of Health Sciences

Appendix D: Plagiarism Declaration

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

FACULTY OF HEALTH SCIENCES

PLAGIARISM DECLARATION TO BE SIGNED BY ALL HIGHER DEGREE STUDENTS

SENATE PLAGIARISM POLICY: APPENDIX ONE

I Dr. Palesa Phalafala (Student number: 301417) am a student registered for the degree of MMED in the academic year 2022.

I hereby declare the following:

- I am aware that plagiarism (the use of someone else's work without their permission and/or without acknowledging the original source) is wrong.
- I confirm that the work submitted for assessment for the above degree is my own unaided work except where I have explicitly indicated otherwise.
- I have followed the required conventions in referencing the thoughts and ideas of others.
- I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this is not my own unaided work or that I have failed to acknowledge the source of the ideas or words in my writing.
- I have included as an appendix a report from "Turnitin" (or other approved plagiarism detection) software indicating the level of plagiarism in my research document.

Signature:  Date: 08/07/2022

Appendix E: Turnitin report

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