Retrospective case series of the anaesthetic management and outcomes of patients with Rasmussen's aneurysms at an academic hospital

Hannah Elizabeth Stuart-Clark

A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg in partial fulfilment of the requirements for the degree of Master of Medicine in the branch of Anaesthesiology.

Johannesburg, 2022

Declaration

I, Hannah Elizabeth Stuart-Clark declare that this research report is my own unaided work. It is being submitted for the Degree of Master of Medicine in the branch of Anaesthesiology at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

21 January 2022

Abstract

Background

Tuberculosis (TB) has a high burden of disease in South Africa and a Rasmussen's aneurysm is a late complication of TB (1-5). Although rare, the risk for life-threatening complications is high (>50%) (6-9). Pulmonary artery embolization (PAE) is a highly specialised, minimally invasive technique used for the management of haemoptysis caused by a Rasmussen's aneurysm which is not commonly performed in Lower Middle-Income Countries (10). There is a paucity of information regarding anaesthetic management guidelines for these patients undergoing PAE.

The aim of this study was to describe the periprocedural anaesthetic management and outcomes of patients presenting with Rasmussen's aneurysms treated with PAE in the interventional radiology suite at Chris Hani Baragwanath Academic Hospital.

Methods

This study was designed as a retrospective case series and arterial embolization (AE) records were collected over a 4.5-year period (January 2017 – June 2021) for evaluation. All patients identified with Rasmussen's aneurysms were included in the study and the anaesthesia charts, patient hospital ward files, records from interventional radiology, the National Health Laboratory Service, and pulmonology patient records were then interrogated.

Results

The prevalence of Rasmussen's aneurysms in patients presenting for PAE with haemoptysis at this institution was 9%. Of the sixteen patients included in the study, thirteen were male and three were female. Current or previous tuberculosis infection was noted in ten patients and five patients had a current or previous history of smoking. The median duration of the general anaesthesia procedures were 4 hours 5 minutes (interquartile range 03:03 - 05:33), with nine cases done electively and eight done as emergencies. A total of 15 patients were intubated using double lumen

endotracheal tubes and 12 patients were done with both consultant and registrar anaesthesiology coverage. Median haemoglobin was 10.5g/dl and eleven patients did not receive periprocedural blood transfusions. All patients were embolised successfully using metallic coils and were sent to a high-dependency unit post-procedure.

Conclusion

Despite the limitations, this study provides several novel insights into the prevalence and anaesthetic management of Rasmussen's aneurysms in patients presenting with haemoptysis for PAE in our setting and helped establish the need for protocolised guidelines for the management of these patients. This data also allowed for the development of a novel set of guide recommendations for the management of this unique subset of patients, which include the following: guidelines for pre-operative optimisation, invasive monitoring, anaesthesia technique and postoperative care.

Acknowledgements

I would like to dedicate this Master's thesis to the memory of my grandfather, Dr Stuart Astley Young. He introduced me to and encouraged my love of science, problem solving and physiology. He encouraged me to persevere when I was struggling with my research, and I know he would have been keen to read and comment on the final document if he was still here.

I would like to give thanks and acknowledgement to the following people for their contributions to making this thesis possible:

- My husband, Daniel Bagshawe, without whom I would not have been able to complete this thesis. His love, support, encouragement, endless cups of tea and statistics help were invaluable,
- My supervisors, Dr Palesa Mogane and Dr Josias Padi for their guidance and assistance with my thesis,
- Dr Jacques Naude for his help with my statistics and advice on approaching research,
- Dr Samantha Faurie for your assistance with editing, formatting, and advice when I needed encouragement to continue,
- Dr Alan Peter from Pulmonology and Dr Daniel Prince from Interventional Radiology at Chris Hani Baragwanath Academic Hospital for their assistance with information on outcomes and procedural management.
- Thabo Mthembu from Chris Hani Baragwanath Academic Hospital Records department for his assistance with obtaining the patient files.

Table of Contents

List of tables

List of figures

Abbreviations

TB	Tuberculosis
AE	Arterial Embolization
BAE	Bronchial Artery Embolization
PAE	Pulmonary Artery Embolization
RA	Rasmussen’s Aneurysm
NORA	Non-operating Room Anaesthesia
CHBAH	Chris Hani Baragwanath Academic Hospital
IR Suite	Interventional Radiology Suite
ETT	Endotracheal Tube
DLT	Double Lumen Endotracheal Tube
SLT	Single Lumen Endotracheal Tube
OLV	One Lung Ventilation
CT Scan	Computerised Tomography Scan
CTPA	Computerised Tomography Pulmonary Angiogram
CTA	Computerised Tomography Angiogram
NICD	National Institute for Communicable Diseases
HIV	Human Immunodeficiency Virus
CIN	Contrast-induced Nephropathy
ASA	American Society of Anaesthesiologists
ICU	Intensive Care Unit

NBCA	N-Butyl cyanoacrylate
PVA	Polyvinyl Alcohol
ABG	Arterial Blood Gas
INR	International Normalised Ratio
aPTT	Activated Partial Thromboplastin Time
IQR	Interquartile Range
O_2 Sats	Oxygen Saturation
Hb	Haemoglobin
SBP	Systolic Blood Pressure
DBP	Diastolic Blood Pressure
MAP	Mean Arterial Blood Pressure
CVC	Central Venous Catheter
A-line	Arterial Line
HR	Heart Rate

Statement

This Research Report consists of a literature review, draft article, study proposal and appendices. The study proposal is included for background reference and is not for examination.

The formatting of this Research Report complies with the University of the Witwatersrand's Style Guide for Theses, Dissertations and Research Reports. The formatting of the draft article may differ from the rest of the Research Report to comply with the author guidelines of the Journal of Anaesthesia, the journal to which it is intended to be submitted.

Chapter 1 Review of the literature

1.1 Introduction

South Africa has a high Tuberculosis (TB) disease burden (1). One of the rarer complications of TB is Rasmussen's aneurysm (1). Anecdotal evidence suggests that clinicians at the Interventional Radiology Suite at Chris Hani Baragwanath Academic Hospital see several Rasmussen's aneurysms every year. Despite this, there is a paucity of information regarding the anaesthetic approach to the management of patients presenting with this condition in the Interventional Radiology Suite. Thus, examination of the current literature can offer us some insights into this condition, its management as well as the anaesthetic approach for these patients.

1.2 Summary of the literature

1.2.1 Tuberculosis

The World Health Organization classifies Tuberculosis (TB) as one of the top ten causes of mortality worldwide, with approximately 10 million cases identified in 2019 (2, 3) with Africa accounting for 25% of annual TB cases globally. The incidence in South Africa is approximately 615 per 100 000 (2, 4) and while the incidence of TB in South Africa, and globally has been decreasing, it still produces a significant public health burden, especially in developing countries (3). The emergence of the Covid-19 pandemic in 2019 has led to concern that the gains made in reducing TB disease may regress due to the reallocation of critical resources in emerging nations (2, 5).

The clinical manifestations of *Mycobacterium tuberculosis* infection vary, with pulmonary disease affecting the lung parenchyma, pleura, airways and vascular structures (6). The differences in presentation are due to the variability in the host's immune system's response to the *Mycobacterium tuberculosis* infection (7). The initial immune response to infection with *Mycobacterium tuberculosis* is to form a granuloma, a highly organised structure which consists of multiple different immune cells such a macrophages, neutrophils, etc. which surround a central caseous

necrotic core (7). Caseous necrosis causes destruction of local alveolar cells, local blood vessels and terminal bronchioles (7). According to Ravimohan *et al,* the exact mechanisms behind the immune response inducing caseous necrosis is poorly understood with several differences noted between animal and human models (7).

As such, patients with pulmonary TB have a high risk for developing long term respiratory complications due to the immune-mediated destruction of their alveoli, terminal bronchioles and pulmonary blood vessels which can result in a significant reduction in their quality of life (7). This damage can be extensive which further impacts on the patient's quality of life (8). Pulmonary pathology can present as fibro-cavitatory disease with chronic cough, dyspnoea and/or haemoptysis (1, 7, 9). Fibro-cavitatory disease and bronchiectasis result in irreversible airway damage and dilatation (1). Blood vessels adjacent to these areas of damage become hypertrophied, ectatic and are more prone to rupture and bleeding (1). As many as 8% of patients may present with haemoptysis which can range from mild to life-threatening, with mortality ranging from 5-25% (6, 10).

Tuberculosis is the leading cause of haemoptysis in developing countries, (11-14), and can occur in patients with active infection or in patients who are post-TB therapy (1). There is limited data assessing the differences in prevalence of haemoptysis in patients with active TB to that of haemoptysis in patients with post-pulmonary TB complications (1). Inflammation and hypoxia induces the propagation of pulmonary blood vessels in response to increases in vascular endothelial growth factor and angiopoietin-1 (14). New blood vessels tend to be thin-walled and prone to rupture (14), with these proangiogenic factors affecting both the bronchial and pulmonary arterial supplies (6, 14-16). In addition, many patients who are post-TB therapy experience distortions in their lung parenchyma and altered vasculature which is prone to rupture resulting in haemoptysis (1).

Minor haemoptysis in active TB is usually self-limiting and often responds to conventional TB therapy (17). Massive haemoptysis in TB occurs due to chronic parenchymal disease, and while it is an uncommon complication it is also life-threatening (14, 17, 18). Massive haemoptysis has a high mortality rate, with more than 75% of patients demising if conservatively managed (13, 14, 18, 19).

1.2.2 The pulmonary blood supply

Human lungs have a dual blood supply, with lower pressure deoxygenated blood passing through the pulmonary arteries and higher pressure oxygenated blood supplied by the bronchial arteries (14). The pulmonary arteries play a role in gaseous exchange, taking deoxygenated, carbon dioxide rich blood from the right ventricle to the lungs (20). The pulmonary arteries interact with the terminal bronchioles and alveoli to facilitate gaseous exchange (20). The bronchial arteries arise from the aorta and follow the respiratory bronchi with their terminal branches overlapping with the pulmonary artery circulation (20, 21). The function of the bronchial arteries is to provide arterial blood to the tracheobronchial tree down to the terminal bronchioles (20). The bronchial arteries also contribute to the blood supply of the visceral pleura, hilar lymph nodes, vagus nerve, oesophagus and the pulmonary arteries and veins (20).

The bronchial arteries branch off from the descending thoracic aorta at the level of the third to the eighth thoracic vertebral bodies, typically between the fifth and sixth thoracic vertebra (20, 21). There are several anatomic variations to the bronchial arteries and at least ten different patterns have been identified (10, 20, 21) . The predominant type arises from a single intercostal trunk at the level of the fifth and sixth thoracic vertebra (20, 21). This single intercostal trunk is typically found on the right side of the aorta and gives rise to the right bronchial arteries and a single left bronchial artery (20, 21). The prevalence of a common bronchial artery trunk is unknown (10). Bronchial arteries that originate outside of the fifth and sixth thoracic vertebra are considered anomalous (10). Approximately 20% of bronchial arteries can have an anomalous origin, arising from other systemic arteries such as the internal mammary artery, aortic arch, subclavian artery, costocervical trunk, etc. (10, 20). The majority of anomalous bronchial arteries arise from the aortic arch (10). Bronchial arteries can anastomose with the terminal branches of the pulmonary veins, allowing for drainage of bronchial artery blood into the left heart (20). In the presence of chronic inflammation, these connections may increase resulting in an increased bleeding risk (20). Normal bronchial arteries have a vascular diameter of 1.5 mm and a diameter greater than 3 mm is considered abnormal (21).

1.2.3 Types of aneurysms

A true aneurysm involves all three layers of the blood vessel wall (intima, media and adventitia) and the risk of rupture is proportional to the size of the aneurysm (22). True aneurysms can be saccular or fusiform and their walls may be attenuated (22). A false aneurysm or pseudoaneurysm is caused by arterial wall damage resulting in a locally contained haematoma, turbulent blood flow and an aneurysmal neck (23). Pseudoaneurysms differ from true aneurysms in that they do not contain any layer of the vessel wall (23). They are abnormal outpouchings or dilatations of arteries which are surrounded by the tunica adventitia (24). Pseudoaneurysms typically occur when there is a breach in the vessel wall due to trauma or infection and the blood is contained by the adventitia or surrounding soft tissue and the products of the coagulation cascade (23, 24).

1.2.4 Rasmussen's aneurysms

Rasmussen's aneurysms were first identified by Fritz Valdemar Rasmussen in 1868 in a series of autopsies conducted on patients with TB mediated haemoptysis (1, 3, 18, 25-29). Traditionally, a Rasmussen's aneurysm is a pseudoaneurysm of a peripheral branch of the pulmonary arteries adjacent to a TB cavity, and typically occurs in the upper lobes of the lung (18, 25, 26, 30-32). However, over time this definition has widened to include any aneurysm or pseudoaneurysm involving the pulmonary arteries in the presence of a disease which causes destruction of the pulmonary parenchyma, such as Behçet's disease (18, 25, 26, 30, 33).

Granulomatous infiltration of the arterial walls causes vascular remodelling following an increase in fibrin deposits and caseation which results in progressive thinning of the vessel wall and subsequent dilatation (1, 32, 34, 35). The weakened vessel wall can leak or rupture causing massive haemoptysis (1). Rasmussen's aneurysms are typically a late presentation of pulmonary damage after the initial TB exposure (36). They can also occur in the presence of disease reactivation with progressive pulmonary cavitation (36). Patients with Rasmussen's aneurysms may present with cough and haemoptysis (37).

Rasmussen's aneurysms are rare, and most case reports describe only a single case, making prevalence difficult to quantify. One autopsy series reported a prevalence of 4 - 5% for Rasmussen's aneurysms while Ivkovic et al., reported a prevalence of 0.25% in 21 532 patients with confirmed TB when evaluated using multidetector computed tomography (1, 25, 26, 38, 39). The exact incidence of Rasmussen's aneurysms has not been reported (40). Although rare, the risk for life-threatening complications such as massive haemoptysis or pulmonary artery dissection is high therefore early identification and management is essential (28, 41). A Rasmussen's aneurysm should be suspected if patients with haemoptysis have a relapse post successful bronchial artery embolization or if massive haemoptysis occurs in the presence of TB with cavitatory disease (42).

The gold standard for investigation is a computed tomography pulmonary angiogram (CTPA) as it provides anatomical information about the Rasmussen's aneurysm, identifies potential causes and guides management (18, 31). However, Rasmussen's aneurysms are not routinely evaluated for and can be missed on CTPA (28). Hypoperfusion of the lung parenchyma distal to the aneurysm can also affect the visualisation of the aneurysm on CTPA (43, 44). Possible causes for failure of CTPA to detect the presence of a Rasmussen's aneurysm include the following (42): the peripheral position of the aneurysm may mean that an inadequate amount of contrast reaches the lesion and thus it does not appear on the CTPA; there may be a vascular tissue flap in the aneurysm which acts as a valve which prevents adequate filling of the aneurysm with contrast; the presence of a thrombus in the aneurysm may impair filling of the aneurysm with contrast; and the presence of a bronchopulmonary shunt can cause hypoperfusion or reverse the direction of blood flow in the diseased pulmonary segment.

1.2.5 Haemoptysis

Massive haemoptysis is challenging to manage and requires aggressive measures to elicit cause and initiate prompt therapy (13). Almost 90% of all cases of haemoptysis arise from bronchial artery bleeds and the remaining 10% of cases are due to pulmonary artery bleeds, 5% of which are due to Rasmussen's aneurysms (14, 19, 25, 45). Mortality in massive haemoptysis occurs due to aspiration of blood resulting in asphyxiation, severe hypoxaemia, and hypotension (11, 13, 46, 47).

Massive haemoptysis was traditionally defined based on the volume of expectorated blood (more than 600 mL of blood over 24 hours, or more than 250 mL in a single episode) (48-50). However, quantifying blood loss can be challenging (14, 51). Clinical features that are suggestive of poor outcomes in patients with massive haemoptysis include the speed of bleeding, evidence of aspiration in the contralateral lung and haemodynamic instability (20). Therefore, it is important to look at the speed of bleeding, the patient's ability to maintain their airway and expectorate blood, the availability of different therapeutic options, the presence of haemodynamic or respiratory compromise and the patient's physiological reserve to determine if the bleed is life-threatening (14, 48-52).

1.2.6 Conservative management of haemoptysis

Chronic mild or moderate haemoptysis can be managed conservatively if the underlying pathology is known (53, 54). Mild haemoptysis is often self-limiting and can be controlled by medical therapy (54). Conservative management includes the treatment of the underlying infection (e.g., anti-tuberculosis therapy), strict bed rest, supplemental oxygen and positioning the patient in the lateral decubitus position with the bleeding site positioned inferiorly if it is known (1, 53-55). Conservative management also includes the optimization of the patient's coagulation status and haemodynamic status (53). The use of intravenous tranexamic acid has been shown to control mild haemoptysis in the setting of cystic fibrosis (53). However, the use of conservative management in massive or life-threatening haemoptysis is associated with increased mortality and is thus not recommended (54). There is also a higher risk of recurrent bleeds with conservative management and therefore it should be used as a complementary method to a more definitive treatment modality (20).

1.2.7 Bronchoscopic management of haemoptysis

Several techniques can be used to achieve haemostasis using a rigid or fibreoptic bronchoscope. These include the instillation of medical therapy into the bronchus via the bronchoscope and the use of thermal ablation techniques (20, 53).

Endobronchial medical therapy is used to achieve haemostasis when the source of bleeding is beyond the reach of the bronchoscope (20). Agents used include cold

saline irrigation, instillation of adrenaline and noradrenaline into the bronchus, administration of antidiuretic hormone derivatives such as terlipressin into the bronchus, and administration of tranexamic acid into the bronchus (20, 53).

The use of thermal ablation requires special training and equipment and should only be used by an experienced provider (20). Thermal ablation is predominantly used for the control of haemoptysis due to malignancies (20). Photocoagulation by laser therapy can be used if the bleeding site is localised to the airway mucosa (20). Electrocauterization with argon is an alternative thermal ablation method. It can be used to induce clot formation and can be effective in managing bleeds arising from the airway mucosa (20). There is a high risk of airway fires with these techniques and precautions should be taken to avoid this (20).

1.2.8 Surgical management of haemoptysis

The use of surgery in the management of haemoptysis has decreased over time with the advent of minimally invasive techniques such as arterial embolization (AE) (20). Patients with massive haemoptysis tend to be poor surgical candidates with reduced respiratory reserve and have an increased risk for post-operative complications such as persistent air leaks, bronchopulmonary fistulae, and coagulopathy (54, 56). This is further complicated by the lack of clear guidelines for perioperative anaesthetic management of these patients (54). A lateral thoracotomy allows for the surgical management of the bleeding vessels followed by either a wedge or segmental resection, a lobectomy or pneumonectomy of the affected lung (20, 54, 57).

The advantage of surgical management is that it provides definitive treatment of massive haemoptysis by removing the source of bleeding (54). However, surgery in these high-risk patients is associated with mortality rates of 7.1-18.2% which increases to 40-50% if the surgery is done in an emergent setting (6, 15, 48, 58, 59). Mortality often arises due to ongoing bleeding with associated haemodynamic instability and contamination of healthy lung segments (43). In addition, when the bleed is life threatening lung function tests may not have been performed to assess the patient's baseline pulmonary reserve function. This means that if the patient needs an emergent pneumonectomy, it may be difficult to predict how the patient

will tolerate the procedure (43). This is of particular importance as patients often have poor respiratory reserve due to their underlying pathology (56).

Appropriate patient selection and timing of surgery improves outcomes and emergent surgery should only be considered in patients who continue to have massive haemoptysis despite minimally invasive interventions (43). Adverse outcomes following surgical intervention tend to be associated with advanced age, pleural adhesions, pneumonectomy and bronchiectasis (20).

1.2.9 Arterial embolization for haemoptysis

The use of arterial embolization (AE) in haemoptysis was first described in 1974 and has become the standard of care for at-risk patients with TB-induced haemoptysis (43, 60). Arterial embolization is a minimally invasive technique which improves mortality in massive haemoptysis to 13-17.8% and has a success rate of approximately 90% (1, 14, 61-63). The use of minimally invasive techniques can preserve pulmonary function and improve prognosis (64, 65), may be used in patients with multiple aneurysms and can function as a bridging therapy to definitive surgical management (1, 64, 66). As such, AE is considered one of the most effective non-surgical treatments for massive haemoptysis (54). Arterial embolization can be applied to either the bronchial or pulmonary arterial systems. Haemoptysis in TB usually arises from the bronchial arteries, and less than 10% of cases are due to pulmonary arterial bleeds (21, 43, 67). Rasmussen's aneurysms are pulmonary arterial pseudoaneurysms. Literature focusing on AE in these patients is often referred to as bronchial artery embolization (BAE). This is a misnomer as the embolization technique to manage Rasmussen's aneurysms is conducted via the pulmonary arterial system, as such it should be referred to as pulmonary artery embolization (PAE).

Traditionally, the interventional radiologist will gain access via the femoral artery and then start with an evaluation of the bronchial arterial system to try to locate the source of bleeding (21). Angiography is performed with iso-osmolar or low-osmolar non-ionic contrast (21). If the source of bleeding cannot be identified, a systematic and sequential review of the pulmonary and systematic circulation will be conducted to try locate the source (68). Anatomic information obtained from CTPA should be

used to guide angiography and the endovascular interventions (37). This is recommended to reduce the risk of rebleeding and improve control of haemoptysis (68). In a resource limited setting such as South Africa, with a high burden of disease of TB, diagnostic tools and specialist management options such as AE may not be readily available which may contribute to the high mortality of massive haemoptysis in these settings (1).

Pulmonary artery aneurysms can be classified into four types based on the CTPA and bronchial angiographic findings (42, 43): Type A (visualised on nonselective catheter directed pulmonary angiography); Type B (visualised on selective catheter directed pulmonary angiography only); Type C (both the bronchial and non-bronchial vascular systems are visualised due to the presence of a bronchial to pulmonary arterial shunt and no feeding pulmonary arteries are visualised during selective pulmonary angiography); and Type D (visualised only by CTPA).

Two embolization techniques have been described: BAE followed by selective PAE if a residual aneurysm is noted on follow up CTPA or haemoptysis reoccurs, or selective PAE followed by BAE if a residual aneurysm is noted on bronchial angiography (43). Bronchial artery embolization is the method of choice for control of haemoptysis, and interventional radiologists may prefer to approach Rasmussen's aneurysms via this technique, especially if it is a Type C Rasmussen's aneurysm (43). However, the bronchial artery can be tortuous with multiple interconnecting branches which can make approaching a Rasmussen's aneurysm via this technique more challenging (43). Using the pulmonary artery to approach a Rasmussen's aneurysm can be simpler due to the short and straight nature of the pulmonary arteries (43). There is a lack of clear treatment guidelines in the literature for the management of Rasmussen's aneurysms (36).

Arterial embolization techniques include the insertion of a gelatin sponge, coils, N-butyl cyanoacrylate (NBCA) glue injection, polyvinyl alcohol (PVA) particle injections, microsphere injection and stent insertion (43, 64). The choice of agent deployed for embolization depends on durability of occlusion, ease of dispatch of the technique, proximal or distal embolization, the potential for recanalization post-embolization and the size of the aneurysm and the feeding vessel lumen (21, 66). The choice of embolization technique is dependent on institutional protocols and

using the correct technique for the aneurysm ensures the safety and success of the intervention (20, 21).

The use of gelatin sponge such as Gelfoam1 is considered to be the most economical (21). However, the use of a microcatheter may make delivery of the gelatin sponge for embolization more technically challenging and there is a high rate of recanalization (21). As such, this technique is not routinely used for the management of Rasmussen's aneurysms.

Polyvinyl alcohol particles are also relatively inexpensive and do not undergo resorption once injected therefore they provide a more durable vascular occlusion (21). However, PVA particles can clump together which can lead to a more proximal occlusion than anticipated, therefore their use is not recommended in the management of Rasmussen's aneurysms (21).

Microspheres consist of cross-linked gelatin and are predominantly used in the embolization of uterine fibroids (21). They are less prone to clumping than PVA particles and have shown some short-term success in in the management of bronchial artery aneurysms (21). Their role in the management of Rasmussen's aneurysms has not been documented in the literature.

The use of NBCA glue is a preferred technique of embolization as this liquid format facilitates the closure of both the aneurysm and its inflow and outflow arteries (43). However, its use in the BAE has been infrequently reported in the literature (21). Theoretically, there is less risk of aneurysmal rupture when using NBCA glue, but its success is operator-dependent and its behaviour can be unpredictable (43). However, there is a risk of distal embolization which can result in the embolization of nontarget arteries and subsequent tissue necrosis (21).

Metallic coils can be used to achieve a proximal occlusion of the affected vessel, however the placement of the metallic coil proximally may inhibit further embolization attempts if rebleeding occurs (21). Proximal occlusion of a Rasmussen's aneurysm does not address collateral flow which can present as recurrent haemoptysis (21). There is limited data on the efficacy of using metallic coils for BAE, however it is the recommended technique employed for the

embolization of pulmonary artery aneurysms (21, 36, 37, 67). There is an increased risk of aneurysmal rupture with the use of metallic coils, as such care must be taken to avoid overpacking the aneurysm or advancing either the catheter or coil through the aneurysmal wall (67).

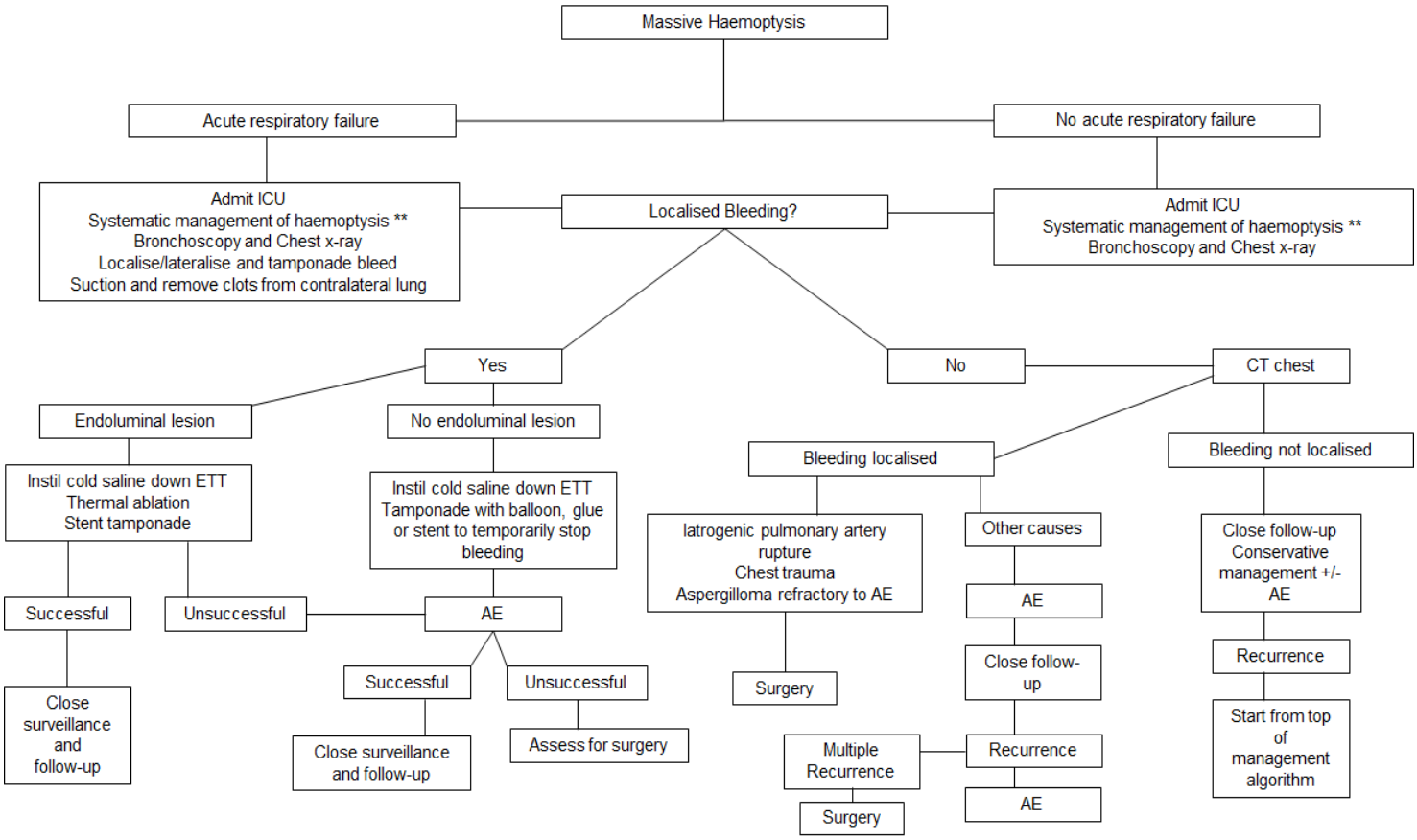
Indiscriminate embolization can result in serious ischaemic complications involving the healthy lung parenchyma (43) and common complications include re-canalisation of embolized arteries, incomplete embolization, growth of collateral blood supply, inadvertent rupture of the aneurysm or arterial dissection, transient chest pain or back pain and dysphagia (14, 60, 64, 69). The most severe complication is spinal cord ischaemia secondary to embolization of the anterior spinal arteries (14).

1.2.10 Management guidelines for patients with massive haemoptysis

In massive haemoptysis, initial management of the patient follows advanced cardiac life support principles which include securing the airway, optimization of oxygenation, and stabilization of their haemodynamic status (6, 13, 20, 70). This often requires the involvement of a multidisciplinary team consisting of the anaesthesiologist, interventional radiologist, pulmonologist, critical care physician and surgeon (36, 70, 71). A systematic approach to management is preferred and is summarised in figure 1-2 (20).

Initial airway management can be accomplished with a single lumen endotracheal tube until the site of the bleeding has been identified, using either fibreoptic bronchoscopy, chest computed tomography angiography (CTA) or AE (13, 20). Once the site of the bleed has been identified, lung isolation can be achieved using several techniques which include the following: a tube exchange with a double-lumen endotracheal tube, the use of a Fogarty catheter or a bronchial blocker, or the advancement of the single-lumen endotracheal tube into the main bronchus of the unaffected side (13). The patient should then be positioned with the bleeding side in the dependent position to optimise oxygenation of the unaffected lung (70). It is important to appropriately blunt the sympathetic response to intubation in these patients as excessive sympathetic stimulation can precipitate an increase in

pulmonary vascular resistance and induce right ventricular failure, aneurysmal rupture and sudden death (59).



Systematic management of haemoptysis **

1. Position patient bleeding side down (if known)
2. Intubation:
   - Rigid intubation
   - Single lumen endotracheal intubation (size ≥ 8.5mm)
3. Contralateral isolation and one lung ventilation
4. Volume resuscitation (Intravenous fluids)
5. Multidisciplinary team:
   - Anaesthesiology
   - Cardiothoracic surgery
   - Interventional Radiology
   - Pulmonology
   - Intensive Care Unit

Figure 1-1 Flow chart describing the systematic approach to the management of massive haemoptysis, start from the top of the flow chart (20)

** see box with systematic management of haemoptysis (adapted from Radchenko et al (20)). Arterial embolization (AE), Endotracheal tube (ETT), Intensive Care Unit (ICU), Computerised Tomography Scan (CT scan).

Arterial embolization provides immediate control of a bleed in 75-90% of patients (13) and the type of anaesthetic technique and fluid management choice is dependent on the patient's condition (71-73). Anaesthetic techniques for AE include sedation with monitored anaesthesia care, regional or neuraxial techniques and general anaesthesia (73). As mentioned above, massive haemoptysis often necessitates the use of lung isolation techniques (72) and patients may also require massive transfusion, inotropic support, and invasive monitoring (70, 72). In patients with mild haemoptysis or those who are stable, the management options are more unclear and there is a general paucity of literature regarding the anaesthetic approach for these patients (72). As such, patients with haemoptysis presenting in interventional radiology are a unique anaesthetic challenge (72).

1.2.11 Anaesthesia for AE

Arterial embolization typically takes place in the interventional radiology suite. This falls under the domain of non-operating room anaesthesia (NORA) (74). Additionally, the rapid expansion of interventional radiology over the last decade has produced a growing demand for anaesthesia support (73-76). However, NORA in the interventional radiology suite can present multiple challenges to the anaesthesiologist (75). These include an unfamiliar location and equipment, lack of drugs or supplies, limited workspace and patient access, uncomfortable positioning of the patient, reduced environmental temperatures, and unfamiliar procedures and personnel (73-75). These challenges can hinder the provision of safe anaesthetic care and protocolised care may help to improve safety and patient experience (74, 75). The anaesthetic technique used depends on the anaesthesiologist's knowledge of the procedure (duration and possible complications), intraoperative and post-operative requirements (72). Patients who are managed in interventional radiology tend to be sicker, older, and more complex than those presenting for traditional surgery (72, 74, 77).

The choice of anaesthetic technique depends on procedure and patient specific considerations (73). Patient specific considerations include haemodynamic instability, altered levels of consciousness with risk of aspiration, inability to lie supine or cooperate due to pain, anxiety or respiratory compromise, a history of difficult airways, presence of obstructive sleep apnoea and patient preference (72,

73). Procedure specific considerations include the type of procedure, duration and complexity of the procedure, the need for unconventional positioning, the need for immobility or intermittent apnoea, and exposure of the patient and anaesthesia team to radiation (73). Appropriate anaesthetic techniques include sedation with monitored anaesthesia care, regional or neuraxial techniques and general anaesthesia (73). Derbent et al. postulate that the use of a permanent anaesthesia interventional radiology team may reduce the complications associated with NORA in the interventional radiology suite (71).

1.2.12 Pre-procedural evaluation

Patient preparation and optimization is essential when determining the anaesthetic approach for the management of a patient with haemoptysis requiring AE. A multidisciplinary approach should be followed as all members of the patients' team should be involved in their optimization (36). Pre-anaesthesia evaluation should include a thorough history and examination to identify potential risk factors and areas for further optimization (78). Special attention should be taken to look for risk factors for contrast-induced nephropathy (CIN) and contrast allergy (78). A patient should be adequately resuscitated where possible especially in the setting of massive haemoptysis (79). This includes optimising oxygenation and correction of hypotension, coagulopathy, anaemia, and electrolyte abnormalities (79).

Investigations should be used to provide a baseline to either direct treatment or assess response to treatment (78). Pre-procedural investigations should be directed by institution-specific protocols and may include the following (20, 78, 79): Chest x-ray, CTPA and CTA, electrocardiogram, pulse oximetry and a room air arterial blood gas, phlebotomy (Full blood count with differential count, coagulation profile, electrolytes, urea and creatinine, and liver function tests), urinalysis, and a type and crossmatch of blood.

Arterial embolization is a minimally invasive technique, as such detection and control of bleeding may be difficult due to lack of visualisation and ability to immediately control the bleeding (78). Data on coagulation test values is equivocal in terms of predicting the potential for bleeding during the procedure but should be considered if the patient has the following risk factors (78): Pre-existing

comorbidities (renal failure, liver disease, thrombocytopaenia, etc.); the use of large interventional devices where there is a possibility of inadvertent entry into a vascular structure; bleeding may only be detected after significant blood loss; and bleeding may be difficult to control.

Interventional radiology procedures can be classified according to bleeding risk, organ system, access site and size of the interventional device required for the procedure (low, moderate, and high) (78, 80). Arterial embolization is considered a moderate risk intervention (78, 80). It is recommended that the patients with moderate bleeding risk have an International Normalised Ratio value (INR) ≤ 1.5, an Activated Partial Thromboplastin Clotting Time ≤1.5x control and a platelet count ≥ 50 x 10^9/L (78, 80).

Arterial embolization requires the injection of contrast medium and renal function tests may be used to estimate the patient's risk for CIN (21, 78). Serum creatinine and estimated glomerular filtration rate are used to assess renal function (78).

Vigilant preparation of the interventional radiology suite (IR suite) is also essential and should be guided by the American Society of Anaesthesiologists recommendations (73). This includes checking monitors, equipment and drugs (73). It is also important to consider the ergonomics of the IR suite. Positioning of the anaesthesia workstation for direct observation by the anaesthesiologist will need to be determined due to the limited space in the IR suite (73). Intravenous line extensions and airway circuit extensions may be necessary due to limited access to the patient (73, 81).

1.2.13 Intraoperative anaesthesia

Arterial embolization can take between 2 to 4 hours to perform (82). General anaesthesia is the preferred technique for AE management of Rasmussen's aneurysms. General anaesthesia provides patient immobility and controlled ventilation and apnoea which permits optimal image acquisition and delivery of treatment (81, 83, 84). Patient immobility is essential for the successful deployment of coil embolization in the event of accidental rupture of the aneurysm (83). Total intravenous anaesthesia or volatile anaesthesia may be used, and the technique is

guided by the anaesthesiologist's preference (81). Management of the airway is discussed above.

Access to the patient during the procedure may be limited due to the ergonomics of the IR suite and the patient's arms may also be tucked into their sides (73, 81). Thus, extension lines and three-way taps may need to be added to the infusion lines to provide better access (73, 81). It is important to consider that administered drugs may have a delayed onset of action due to the dead space in the infusion lines due to the addition of extension lines (81). Patients should have at least two peripheral intravenous catheters for the procedure (81).

Monitoring should follow the American Society of Anaesthesiologist guidelines (73). The type of monitoring used should be adapted to the baseline medical status of the patient (81). Routine monitoring such as pulse oximetry, non-invasive blood pressure and electrocardiogram may need to be supplemented with invasive haemodynamic monitoring such as arterial blood pressure and central venous pressure monitoring (81). Close monitoring of haemodynamics is essential as it assists in ensuring adequate sympathetic suppression thus avoiding an increase in pulmonary vascular resistance and the risk of aneurysmal rupture (59).

Core temperature should be monitored as patient hypothermia can occur due to the cold ambient temperature of the IR suite and the prolonged duration of the procedure (75, 76, 81). Urine output should also be measured and frequently assessed as large volumes of fluid may be used to flush the arterial catheters and the osmotic load of the contrast medium may cause excessive diuresis (81).

The Society of Interventional Radiology recommend that staff in the IR suite have up-to-date advanced cardiac life support certification (84-86). The anaesthesiologist plays a role in providing cardio-respiratory support in the event of adverse events such as aneurysmal rupture and bleeding. Appropriate ventilation strategies should be used to avoid increases in pulmonary vascular resistance (59).

1.2.14 Post-procedural management

On completion of the AE procedure, the interventional radiologist will remove the femoral artery catheter and compress the groin to assist with haemostasis (79).

Patients should be admitted to a high dependency or intensive care unit (ICU) post-procedure for close monitoring and routine post-arterial embolization care to reduce the risk of adverse outcomes such as bleeding (79, 82, 85). Post-arterial embolization care includes the following (79, 82): Bed rest where the patient must lie flat for the first hour and avoid bending the leg on the side of the femoral artery catheter insertion; regular vital sign readings as per the unit's protocol; regular inspection of the access site and peripheral pulse checks with each vitals check to monitor for bleeding and vessel occlusion; adequate analgesia and antiemetic therapy; and ensure adequate fluid intake and monitor urine output to prevent renal dysfunction.

If the patient's condition allows, the anaesthesiologist should aim to extubate the patient at the end of their AE. Respiratory complications occur more commonly on emergence and tracheal extubation than with induction and tracheal intubation (87). Previous difficulty in securing the airway and patients with an increased risk of aspiration need to be considered when planning for tracheal extubation (87). Tracheal extubation is associated with a 10-30% increase in heart rate and blood pressure (87). In Rasmussen's aneurysms, blunting the extubation response is important to avoid the adverse effects of excessive sympathetic stimulation (59). Excessive sympathetic stimulation can precipitate rupture of the aneurysm (59). Sympathetic stimulation can be attenuated by the administration of any of the following agents: esmolol, magnesium sulphate, intravenous or topical lignocaine, or propofol (87).

Patients with Rasmussen's aneurysms may have pre-existing poor respiratory function secondary to TB fibro-cavitatory disease and may have an increased risk of bronchospasm at extubation (85, 87). Tracheal extubation should be timed with the end of inspiration as this has been shown to reduce the risk of laryngospasm (87, 88).

Patients with chronic lung disease also have an increased risk of post-operative hypoxaemia (85, 87). This can be caused by inadequate minute ventilation, diffusion hypoxia, mucociliary dysfunction, hypoxic pulmonary vasoconstriction, and post-hyperventilation hypoventilation (85, 87, 89). Administration of 100% oxygen can

help prevent atelectasis and assist in the management of post-operative hypoxaemia (87, 88).

If extubation is not possible after the AE, the patient should be transferred to the ICU intubated with 100% oxygen (87). The decision to extubate in ICU is protocol driven (87). Classical weaning criteria have been shown to have poor accuracy in detecting the outcome of extubation (87). However, a cuff leak test and/or a spontaneous breathing trial via a T-piece have been shown to have high sensitivity in predicting successful extubation (87).

1.3 Conclusion

Rasmussen's aneurysms are rare, and as such there is a paucity of data with regards to the anaesthetic management of these patients inside the interventional radiology suite. As discussed, the growing popularity of minimally invasive techniques such as AE means that anaesthesia support in the interventional radiology suit is becoming more frequent. Despite this, there are no clear or definitive therapeutic guidelines for the management of patients with Rasmussen's aneurysm under these conditions (90, 91). Patients presenting with Rasmussen's aneurysms at the interventional radiology suite at Chris Hani Baragwanath Academic Hospital provides a unique opportunity to study a cohort of these patients, which are usually represented in literature as individual case reports. The results of this study should provide the opportunity to explore this unique burden of disease to provide insight into the anaesthetic management techniques used for patients with Rasmussen's aneurysms as well as provide demographic information and outcomes of the interventions.

1.4 References

1. Seedat UF, Seedat F. Post-primary pulmonary TB haemoptysis – When there is more than meets the eye. Respir Med Case Rep. 2018;25:96-9.doi: 10.1016/j.rmcr.2018.07.006

2. World Health Organization. Global tuberculosis report Geneva: World Health Organization; 2020 [cited 2021 1 November]. Available from: https://apps.who.int/iris/bitstream/handle/10665/336069/9789240013131-eng.pdf.

3. Giraldo-Montoya ÁM, Rodríguez-Morales AJ, Hernández-Hurtado JD, López-Salazar Á, Lagos-Grisales GJ, Ruiz-Granada VH. Rasmussen aneurysm: A rare but not gone complication of tuberculosis. Int J Infect Dis. 2018;69:8-10.doi: 10.1016/j.ijid.2018.01.023

4. World Health Organization. Tuberculosis Geneva: World Health Organisation; 2020 [cited 2020 20 December]. Available from: https://www.who.int/news-room/fact-sheets/detail/tuberculosis.

5. National Institute for Communicable Diseases. Microbiologically confirmed tuberculosis 2004 -15, South Africa. In: Service NHL, editor. South Africa: NICD; 2017.

6. Syed M, Irby J. Airway management of ruptured pulmonary artery “Rasmussen” aneurysm and massive hemoptysis. BMC Res Notes. 2015;8(1):346.doi: 10.1186/s13104-015-1313-7

7. Ravimohan S, Kornfeld H, Weissman D, Bisson GP. Tuberculosis and lung damage: from epidemiology to pathophysiology. Eur Respir Rev. 2018;27(147):170077.doi: 10.1183/16000617.0077-2017

8. Chen G, Zhong F-M, Xu X-D, Yu G-C, Zhu P-F. Efficacy of regional arterial embolization before pleuropulmonary resection in 32 patients with tuberculosis-destroyed lung. BMC Pulm Med. 2018;18(1):156.doi: 10.1186/s12890-018-0722-5

9. Chatterjee K, Colaco B, Colaco C, Hellman M, Meena N. Rasmussen's aneurysm: A forgotten scourge. Respir Med Case Rep. 2015;16:74-6.doi: 10.1016/j.rmcr.2015.08.003

10. Yoon W, Kim JK, Kim YH, Chung TW, Kang HK. Bronchial and nonbronchial systemic artery embolization for life-threatening hemoptysis: a comprehensive review. Radiographics. 2002;22(6):1395-409.doi: 10.1148/rg.226015180

11. Chung MY, Jeong H-D, Kim S-G, Kim CJ. Hemoptysis during general anesthesia in a diabetic patient with healed tuberculosis: a case report. Korean J Anesthesiol. 2017;70(1):86-9.doi: 10.4097/kjae.2017.70.1.86

12. Johnson JL. Manifestations of hemoptysis. How to manage minor, moderate, and massive bleeding. Postgrad Med. 2002;112(4):101-6, 8-9, 13.doi: 10.3810/pgm.2002.10.1335

13. Håkanson E, Konstantinov IE, Fransson SG, Svedjeholm R. Management of life-threatening haemoptysis. Br J Anaesth. 2002;88(2):291-5.doi: 10.1093/bja/88.2.291

14. Davidson K, Shojaee S. Managing massive hemoptysis. Chest. 2020;157(1):77-88.doi: 10.1016/j.chest.2019.07.012

15. Picard C, Parrot A, Boussaud V, Lavolé A, Saidi F, Mayaud C, et al. Massive hemoptysis due to Rasmussen aneurysm: detection with helicoidal CT angiography

and successful steel coil embolization. Intensive Care Med. 2003;29(10):1837-9.doi: 10.1007/s00134-003-1912-y

16. Corr P. Pulmonary artery aneurysm as a cause of massive hemoptysis: diagnosis and management. Case Rep Radiol. 2011;2011:141563-.doi: 10.1155/2011/141563

17. Rajamannar KV, Kilaru H, Aravelly S, Gudipati AR, Kilaru SC. Massive hemoptysis from Rasmussen's aneurysm in active pulmonary tuberculosis; A case report of successful treatment with bronchial artery embolization. Respir Med Case Rep. 2017;22:277-9.doi: 10.1016/j.rmcr.2017.10.003

18. Oriol A, Ayala Carbonero A, Sarasúa L. Hemoptisis amenazante secundaria a aneurisma de Rasmussen en paciente VIH (Life-Threatening Hemoptysis Secondary to Rasmussen's Aneurysm in an HIV Patient). Arch Bronconeumol. 2016;52:439 - 40.doi: 10.1016/j.arbr.2016.06.007

19. Shih S-Y, Tsai IC, Chang Y-T, Tsan Y-T, Hu S-Y. Fatal haemoptysis caused by a ruptured Rasmussen's aneurysm. Thorax. 2011;66(6):553.doi: 10.1136/thx.2010.135616

20. Radchenko C, Alraiyes AH, Shojaee S. A systematic approach to the management of massive hemoptysis. J Thorac Dis. 2017:S1069-S86.doi: 10.21037/jtd.2017.06.41

21. Sopko DR, Smith TP. Bronchial artery embolization for hemoptysis. Semin Intervent Radiol. 2011;28(1):48-62.doi: 10.1055/s-0031-1273940

22. Iqbal S. True aneurysm: Radiopedia.org; 2020 [updated 12 October 2020; cited 2021 3 December]. Available from: https://radiopaedia.org/articles/true-aneurysm?lang=us.

23. Rivera P, Dattilo J. Pseudoaneurysm Treasure Island, Florida: StatPearls Publishing; 2020 [updated 13 September 2020; cited 2021 1 November]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK542244/.

24. D'Souza D, Ashraf A. False aneurysm: Radiopedia.org; 2008 [updated 19 November 2021; cited 2021 8 December]. Available from: https://radiopaedia.org/articles/1326.

25. Santelli ED, Katz DS, Goldschmidt AM, Thomas HA. Embolization of multiple Rasmussen aneurysms as a treatment of hemoptysis. Radiology. 1994;193(2):396-8.doi: 10.1148/radiology.193.2.7972750

26. Auerbach O. Pathology and pathogenesis of pulmonary arterial aneurysm in Tuberculous cavities. Am Rev Tuberc. 1939;39(1):99-115.doi: 10.1164/art.1939.39.1.99

27. Chiu H-W, Kuo S-H, Lai R-S, Wu M-T, Wu H-F. Ambiguous presentation of Mycobacterium avium complex-associated Rasmussen aneurysm. Respirol Case Rep. 2017;5(3):e00219.doi: 10.1002/rcr2.219

28. Sapra R, Sharma G, Minz AK. Rasmussen's aneurysm: A rare and forgotten cause of hemoptysis. Indian Heart J. 2015;67:S53-S6.doi: 10.1016/j.ihj.2015.07.009

29. Neelakantan S, Anandarajan R, Swamy AK. Rare cause of massive haemoptysis in pulmonary tuberculosis: Rasmussen's aneurysm. BMJ Case Rep. 2016;2016:bcr2016216652.doi: 10.1136/bcr-2016-216652

30. Nguyen ET, Silva CIS, Seely JM, Chong S, Lee KS, Müller NL. Pulmonary artery aneurysms and pseudoaneurysms in adults: Findings at CT and radiography. AJR Am J Roentgenol. 2007;188(2):W126-W34.doi: 10.2214/AJR.05.1652

31. Park HS, Chamarthy MR, Lamus D, Saboo SS, Sutphin PD, Kalva SP. Pulmonary artery aneurysms: diagnosis & endovascular therapy. Cardiovasc Diagn Ther. 2018;8(3):350-61.doi: 10.21037/cdt.2018.04.01

32. Badawy A, Feger J. Rasmussen aneurysm: Radiopedia.org; 2021 [updated 21 August 2021; cited 2021 3 December]. Available from: https://radiopaedia.org/articles/rasmussen-aneurysm?lang=us.

33. Samano M, Ladeira R, Meireles L, Pego-Fernandes P. Aneurisma de artéria pulmonar como manifestação da doença de Behçet (Pulmonary artery aneurysm as a manifestation of Behcet disease: case report and review). J Bras Pneumol. 2002;28:150-4.doi: 10.1590/S0102-35862002000300007

34. Kim HY, Song K-S, Goo JM, Lee JS, Lee KS, Lim T-H. Thoracic sequelae and complications of Tuberculosis. Radiographics. 2001;21(4):839-58.doi: 10.1148/radiographics.21.4.g01jl06839

35. Leung AN. Pulmonary Tuberculosis: The essentials. Radiology. 1999;210(2):307-22.doi: 10.1148/radiology.210.2.r99ja34307

36. Pelage J-P, Hajjam ME, Lagrange C, Chinet T, Vieillard-Baron A, Chagnon S, et al. Pulmonary Artery Interventions: An Overview. Radiographics. 2005;25(6):1653-67.doi: 10.1148/rg.256055516

37. Chen Y, Gilman MD, Humphrey KL, Salazar GM, Sharma A, Muniappan A, et al. Pulmonary Artery Pseudoaneurysms: Clinical Features and CT Findings. AJR Am J Roentgenol. 2017;208(1):84-91.doi: 10.2214/ajr.16.16312

38. Sahoo S, Panigrahi MK, Naik S, Mohapatra PR. Rasmussen’s aneurysm masquerading as mass lesion. BMJ Case Rep. 2020;13(2):e232669.doi: 10.1136/bcr-2019-232669

39. Ivkovic S, Milosavljevic T, Ivkovic A. MDCT with angiography in Rasmussen aneurysms. Eur Respir J. 2014;44(Suppl 58):P2631

40. Campos LG, da Silva EC, Rangel AFR, de Souza MD, Musso C. Pulmonary artery aneurysm rupture. Autops Case Rep. 2019;10(1):e2019131-e.doi: 10.4322/acr.2019.131

41. Gupta M, Agrawal A, Iakovou A, Cohen S, Shah R, Talwar A. Pulmonary artery aneurysm: a review. Pulm Circ. 2020;10(1):2045894020908780.doi: 10.1177/2045894020908780

42. Shin TB, Yoon SK, Lee KN, Choi JS, Kim YH, Sung CG, et al. The role of pulmonary CT angiography and selective pulmonary angiography in endovascular management of pulmonary artery pseudoaneurysms associated with infectious lung diseases. J Vasc Interv Radiol. 2007;18(7):882-7.doi: 10.1016/j.jvir.2007.04.023

43. Ugajin A, Fujii H, Nakamura H, Fujita A, Sasaki T, Mato N, et al. Transcatheter proximal coil blocking with n-Butyl-2-Cyanoacrylate injection via the pulmonary artery alone for Rasmussen's aneurysm. Case Rep Radiol. 2019;2019:1725238.doi: 10.1155/2019/1725238

44. Tanahashi Y, Kondo H, Osawa M, Yamamoto T, Yamaguchi M, Furui S. Transcatheter embolization of a Rasmussen aneurysm via pulmonary artery with n-butyl cyanoacrylate and iodized oil mixture injection with balloon occlusion. J Vasc Surg Cases Innov Tech. 2016;2(4):161-4.doi: 10.1016/j.jvscit.2016.09.008

45. Khalil A, Parrot A, Nedelcu C, Fartoukh M, Marsault C, Carette MF. Severe hemoptysis of pulmonary arterial origin: signs and role of multidetector row CT angiography. Chest. 2008;133(1):212-9.doi: 10.1378/chest.07-1159

46. Wang Y-L, Hong C-L, Chung Han S, Ho Angie CY, Yu Chi L, Liu H-P, et al. Massive hemoptysis after the initiation of positive pressure vntilation in a patient with pulmonary Tuberculosis. Anesthesiology. 2000;92(5):1480-.doi: 10.1097/00000542-200005000-00040

47. Winter SM, Ingbar DH. Massive hemoptysis: pathogenesis and management. J Intensive Care Med. 1988;3(3):171-88.doi: 10.1177/088506668800300306

48. Heijkoop B, Gillespie H, Kiroff G. Emergency management of massive haemoptysis. BMJ Case Rep. 2019;12(1).doi: 10.1136/bcr-2018-225620

49. Chandra AS, Rajalingam K, V. KBR, Prasad PK. A study of lung resection for haemoptysis with or without pre-operative bronchial artery embolisation. Int Surg J. 2016;3(3):5.doi: 10.18203/2349-2902.isj20162709

50. Noë GD, Jaffé SM, Molan MP. CT and CT angiography in massive haemoptysis with emphasis on pre-embolization assessment. Clin Radiol. 2011;66(9):869-75.doi: 10.1016/j.crad.2011.03.001

51. Ibrahim WH. Massive haemoptysis: the definition should be revised. Eur Respir J. 2008;32(4):1131.doi: 10.1183/09031936.00080108

52. Adlakha A, Capel I, Addala D, Davis P, Wong A. Acute life-threatening massive haemoptysis in a patient with a predicted difficult airway and emphysematous lung disease. Anaesth Cases. 2018;6(2):37-41.doi: 10.21466/ac.ALMHIAP.2018

53. Ittrich H, Bockhorn M, Klose H, Simon M. The Diagnosis and Treatment of Hemoptysis. Dtsch Arztebl Int. 2017;114(21):371-81.doi: 10.3238/arztebl.2017.0371

54. Zhang Y, Chen C, Jiang G-n. Surgery of massive hemoptysis in pulmonary tuberculosis: Immediate and long-term outcomes. J Thorac Cardiovasc Surg. 2014;148(2):651-6.doi: 10.1016/j.jtcvs.2014.01.008

55. Yazıcıoğlu A, Yekeler E, Yazıcı Ü, Aydın E, Taştepe İ, Karaoğlanoğlu N. Management of Massive Hemoptysis: Analyses of 58 Patients. Turk Thorac J. 2016;17(4):148-52.doi: 10.5152/TurkThoracJ.2016.002

56. Sanyika C, Corr P, Royston D, Blyth DF. Pulmonary angiography and embolization for severe hemoptysis due to cavitary pulmonary tuberculosis. Cardiovasc Intervent Radiol. 1999;22(6):457-60.doi: 10.1007/s002709900432

57. Dokhan AL, Abd Elaziz ME, Yousif M. Surgical management of hemoptysis in pulmonary tuberculous patients. J Egyptian Soc Cardiothorac Surg. 2016;24(1):78-85.doi: 10.1016/j.jescts.2016.05.004

58. Fernando HC, Stein M, Benfield JR, Link DP. Role of bronchial artery embolization in the management of hemoptysis. Arch Surg. 1998;133(8):862-6.doi: 10.1001/archsurg.133.8.862

59. Balcı E, Demir A, Özgök A, Karadeniz Ü. Anaesthesia management in idiopathic pulmonary artery aneurysm surgery. Turk J Anaesthesiol Reanim. 2019;47(6):503-6.doi: 10.5152/TJAR.2019.21447

60. Panda A, Bhalla AS, Goyal A. Bronchial artery embolization in hemoptysis: a systematic review. Diagn Interv Radiol. 2017;23(4):307-17.doi: 10.5152/dir.2017.16454

61. Lee BR, Yu JY, Ban HJ, Oh IJ, Kim KS, Kwon YS, et al. Analysis of patients with hemoptysis in a tertiary referral hospital. Tuberc Respir Dis. 2012;73(2):107-14.doi: 10.4046/trd.2012.73.2.107

62. Ong T-H, Eng P. Massive hemoptysis requiring intensive care. Intensive Care Med. 2003;29(2):317-20.doi: 10.1007/s00134-002-1553-6

63. Reechaipichitkul W, Latong S. Etiology and treatment outcomes of massive hemoptysis. Southeast Asian J Trop Med Public Health. 2005;36(2):474-80.PMID: 15916059

64. Harmon TS, Kaleka G, Maciolek LM, Kathuria MK, Gill GS, Hussain A, et al. Becoming the standard: Expanding the conventional use of interventional

embolization for ruptured pulmonary artery aneurysms. Cureus. 2018;10(11):e3576-e.doi: 10.7759/cureus.3576

65. Matsumura Y, Shiono S, Saito K, Sato T. Pulmonary artery pseudoaneurysm after lung resection successfully treated by coil embolization. Interact Cardiovasc Thorac Surg. 2010;11(3):364-5.doi: 10.1510/icvts.2010.236661

66. Jagia P, Sharma S, Juneja R, Guleria R. Transcatheter treatment of pulmonary artery pseudoaneurysm using a PDA closure device. Diagn Interv Radiol. 2011;17(1):92-4.doi: 10.4261/1305-3825.Dir.2657-09.1

67. Parakh R, Gupta K, Yadav A, Grover T, Satwik A, Agarwal S. Endovascular treatment for peripheral pulmonary artery aneurysm. Vascular. 2010;18(1):37-40.doi: 10.2310/6670.2009.00056

68. Kathuria H, Hollingsworth HM, Vilvendhan R, Reardon C. Management of life-threatening hemoptysis. J Intensive Care. 2020;8(1):23.doi: 10.1186/s40560-020-00441-8

69. Ianniello A, Carrafiello G, Nicotera P, Vaghi A, Cazzulani A. Endovascular treatment of a ruptured pulmonary artery aneurysm in a patient with Behçet's disease using the Amplatzer Vascular Plug 4. Korean J Radiol. 2013;14(2):283-6.doi: 10.3348/kjr.2013.14.2.283

70. Segura-Salguero JC, Díaz-Bohada L, Lutz-Peña JR, Posada AM, Ronderos V. Perioperative management of massive hemoptysis during flexible bronchoscopy: Case report. Rev Colomb de Anestesiol. 2017;45(3):256-61.doi: 10.1016/j.rcae.2017.05.001

71. Derbent A, Oran I, Parildar M, Yurtseven T, Uyar M, Memiş A. Adverse effects of anesthesia in interventional radiology. Diagn Interv Radiol. 2005;11(2):109-12.PMID: 15957099

72. Landrigan-Ossar M. Common procedures and strategies for anaesthesia in interventional radiology. Curr Opin Anaesthesiol. 2015;28(4):458-63.doi: 10.1097/aco.0000000000000208

73. Azizad O, Joshi G. Overview of anesthesia for interventional radiology Waltham, (MA): UpToDate.com; 2019 [updated 19 August 2019; cited 2021 17 February]. Available from: https://www.uptodate.com/contents/overview-of-anesthesia-for-interventional-radiology-procedures?search=anaesthesia%20interventional%20radiology&source=search_result&selectedTitle=1~150&usage_type=default&display_rank=1.

74. Chang B, Kaye AD, Diaz JH, Westlake B, Dutton RP, Urman RD. Interventional procedures outside of the operating room: Results from the National Anesthesia Clinical Outcomes Registry. J Patient Saf. 2018;14(1):9-16.doi: 10.1097/pts.0000000000000156

75. Amin A, Lane JS. The future of anesthesia for interventional radiology. Curr Opin Anaesthesiol. 2018;31(4):469-72.doi: 10.1097/aco.0000000000000609

76. Vari A, Gangi A. Anesthesia practices for interventional radiology in Europe. Cardiovasc Intervent Radiol. 2017;40(6):803-13.doi: 10.1007/s00270-017-1576-6

77. Selzer AR, Murrell M, Shostak E. New trends in interventional pulmonology. Curr Opin Anaesthesiol. 2017;30(1):17-22.doi: 10.1097/aco.0000000000000414

78. Taslakian B, Georges Sebaaly M, Al-Kutoubi A. Patient Evaluation and Preparation in Vascular and Interventional Radiology: What Every Interventional Radiologist Should Know (Part 1: Patient Assessment and Laboratory Tests). Cardiovasc Intervent Radiol. 2016;39(3):325-33.doi: 10.1007/s00270-015-1228-7

79. Kandarpa K, Machan L, Durham J. Handbook of Interventional Radiologic Procedures. Hagerstown, UNITED STATES: Wolters Kluwer; 2016.

80. Kohi MP, Fidelman N, Behr S, Taylor AG, Kolli K, Conrad M, et al. Periprocedural Patient Care. RadioGraphics. 2015;35(6):1766-78.doi: 10.1148/rg.2015150038

81. Garg R, Pandey RM, Darlong V, Punj J. Anaesthetic considerations for Interventional Radiology. Inter J Anesthesiol. 2008;19

82. Oxford Centre for Respiratory Medicine. Bronchial Artery Embolisation: Information for patients. In: Trust ORHN, editor.: Oxford Radcliffe Hospitals NHS Trust; 2010. p. 9-10.

83. Watkinson A, Francis I, Torrie P, Platts AD. The role of anaesthesia in interventional radiology. Br J Radiol. 2002;75:105-6.doi: 10.1259/bjr.75.890.750105

84. Schenker MP, Martin R, Shyn PB, Baum RA. Interventional Radiology and Anesthesia. Anesthesiol Clin. 2009;27(1):87-94.doi: 10.1016/j.anclin.2008.10.012

85. Martin ML, Lennox PH. Sedation and Analgesia in the Interventional Radiology Department. J Vasc Interv Radiol. 2003;14(9):1119-28.doi: 10.1097/01.RVI.0000086536.86489.82

86. Baerlocher MO, Kennedy SA, Ward TJ, Nikolic B, Bakal CW, Lewis CA, et al. Society of Interventional Radiology Position Statement: Staffing Guidelines for the Interventional Radiology Suite. J Vasc Interv Radiol. 2016;27(5):618-22.doi: 10.1016/j.jvir.2016.02.010

87. Karmarkar S, Varshney S. Tracheal extubation. BJA Educ. 2008;8(6):214-20.doi: 10.1093/bjaceaccp/mkn036

88. Jubb A, Ford P. Extubation after anaesthesia: A systematic review. Update Anaesth. 2009;25:30-6

89. Kreibich M, Siepe M, Kroll J, Höhn R, Grohmann J, Beyersdorf F. Aneurysms of the Pulmonary Artery. Circulation. 2015;131(3):310-6.doi:10.1161/CIRCULATIONAHA.114.012907

90. Haj-Yahia S, Sbaih M, Bali K, Darwazah A, Othman W, Zaghari M, et al. Case report and management approach in idiopathic pulmonary arteries aneurysm. J Cardiothorac Surg. 2018;13(1):110-.doi: 10.1186/s13019-018-0791-9

91. Veldtman GR, Dearani JA, Warnes CA. Low pressure giant pulmonary artery aneurysms in the adult: natural history and management strategies. Heart. 2003;89(9):1067-70.doi: 10.1136/heart.89.9.1067

Chapter 2 Author's guidelines (Journal of Anesthesia)

Submission categories

Manuscripts should be prepared and submitted in accordance with the "Uniform Requirements for Manuscripts (URM) Submitted to Biomedical Journals" at: http://www.icmje.org/

Editorial policies

Originality: All manuscripts and materials are received with the understanding that they have not been published elsewhere and are not under consideration for publication elsewhere in whole or in any significant part. Except for a scientific abstract, no substantial part of an article may have been published elsewhere.

Authors who have any question concerning what may constitute prior publication should submit the title page and abstract of previously published material with articles intended for publication in the Journal of Anaesthesia.

Authorship: Manuscripts and all other materials are received with the understanding that each author listed has participated in the conception, design, execution, and/or analysis of data (as applicable), as well as in the writing of the manuscript.

The signatory to the Certification Form, namely the corresponding author, attests to the accuracy and validity of the contents of the manuscript and is listed as author or otherwise acknowledged for his or her contribution. Manuscripts and all other materials are received with the understanding that all authors listed have reviewed the submitted paper and have approved its submission for publication.

No editing by the author(s) is permitted once the manuscript is received at the Editorial Office.

Peer review process: Submitted manuscripts are reviewed with regard to their validity, originality, and significance. All manuscripts are initially assessed by the editors, and if they are judged suitable candidates for publishing, they are then

reviewed by a minimum of two reviewers. In principle, the author will be advised within 8 weeks of the acceptance, rejection, or required revision of the manuscript.

All revisions will require a final editorial review, and resubmission does not guarantee acceptance of the revision.

After submission, authors can return periodically to the journal's Editorial Manager site and monitor the progress of their submission throughout the review process.

Ethical concerns

Patient identification: Patients' names, initials, hospital numbers, admission dates, and any other data that might identify patients are to be avoided in all materials. In addition, a patient must not be recognizable in any photograph or family tree, unless written permission of the subject or, in the case of minors, of parents is provided and included with the submission.

Human studies: Investigations on humans must be conducted in accordance with the current Declaration of Helsinki. No manuscript describing investigations carried out in humans will be accepted for publication unless the text states that the study (either prospective, retrospective, or a report of case series) was approved by research ethics committees of all the involved institutions, and that written informed consent (unless the ethics committees granted a waiver of it) was obtained from all subjects or, in the case of minors, from parents.

The Declaration of Helsinki issued in 2008 states that every clinical trial must be registered in a publicly accessible database before recruitment of the first subject.

The Journal of Anaesthesia has decided that, as of April 1, 2013, it is mandatory for the authors to indicate a registration site and a registration number in the Methods section of all prospective clinical studies that started after April 1, 2009, in any part of the world.

For clinical studies carried out in Japan, the Japanese Ministry of Health, Labour and Welfare states in the Ethical Guidelines for Clinical Research that clinical trials started after April 1, 2009, in Japan must be registered in one of the following

databases (called Japan Primary Registries Network: JPRN), before recruitment of the first subject: (1) UMIN Clinical Trial Registry, (2) Clinical Trials Information (JapicCTI), or (3) Clinical Trial Registry.

Appropriate institutional review board (IRB) review and approval should accompany all studies involving human participants or research material derived from human participants. This information should be clearly stated in the Method section of the manuscript including the date of the IRB approval and duration of the trial/study. If the study was exempted from IRB approval, that information should be indicated in the Method section.

Animal studies: No manuscript describing investigations carried out in animals will be accepted for publication unless the text clearly states that the study was approved by animal research ethics committees. Although it is recognized that animal research ethical guidelines can vary between countries, the Journal of Anaesthesia uses guidelines for proper conduct of animal experiments issued by both the Japanese Ministry of Education, Culture, Sports, Science and Technology and the Japanese Ministry of Health, Labour and Welfare and also by the Science Council of Japan, and reserves the right to reject manuscripts according to our standards, even if the study has been approved by a local ethics committee.

For both human and animal studies, the authors must submit a copy of an approval document from the ethics committee and of written informed consent, when the editorial office or a reviewer requires.

Conflict-of-interest policy

The author must indicate all sources of funding supporting the submitted work. This requirement includes any corporate or institutional funding sources.

Sources of funding and any other explanatory information regarding conflict of interest (COI) for the article should be disclosed when submitting the manuscript via Editorial Manager. Only in exceptional cases does the journal consider COI in the peer-review process. However, the COI may be disclosed in published articles at the discretion of the Editor-in-Chief.

Manuscript format

All manuscripts must be written in English. Manuscripts should be written in American English, not in British English.

The abstract, the manuscript text, references, tables, and figure legends must be typed double-spaced with wide margins in A4-size or U.S. letter-size format. Incomplete or improperly prepared manuscripts will be returned to authors without review.

Each of the following sections must begin on a new page: title page, abstract, manuscript text, references, tables, figure legends, and figures. Pages must be numbered consecutively, beginning with the title page, in the upper right-hand corner of each page.

Standard abbreviations should be used. Abbreviations must be defined in the abstract, at first mention in the manuscript text, and on first occurrence in tables and figure legends. The use of abbreviations in titles and headings should be avoided.

Authors whose native language is not English are required to seek the assistance of language services or of a colleague who is a native English speaker and is familiar with the field of work before the submission.

Maximum length:

Original articles 4,000 words

Title page (page 1): All submissions must include a title page. The title page should contain a brief and specific title and the full names and academic affiliations of all authors. The corresponding author should be specified, with full mailing address, a fax number, and an e-mail address. The title page should include 3–5 key words, and the word count (letter count for Letter to the Editor) of the manuscript, the number of tables, and the number of figures should be indicated.

Abstract: For Original articles, a structured abstract with the headings Purpose, Methods, Results, and Conclusion should be provided. The abstract should consist

of no more than 250 words and should include only the most essential data, along with the statistical significance, if available. New and important aspects of the study should be emphasized.

Manuscript text:

The manuscript text of original articles should be divided into the following sections. (Short communications should not include subdivisions such as Methods, Results, etc.)

Introduction:

The introduction should provide a concise account of the background and purpose of the study, containing only the most pertinent references, not an extensive literature review.

Methods:

This section should clearly describe the selection criteria for subjects of observations or experiments. The methods and apparatus used must be described in sufficient detail to allow the investigation to be interpreted and repeated. All technical apparatus, including computer software, must be identified in parentheses with brand name, manufacturer's name, and city and country of manufacture (if U.S.A., both city and state). Complete references must be provided for all established scientific methods and medical procedures, and any lesser-known methods should be described briefly. All drugs and chemicals used must be identified, specifying dosage and routes of administration. Generic names for drugs are preferable; if a brand name is used, it should be inserted in parentheses after the generic name. The standard units for length, mass, and volume are meter, kilogram, and litre, respectively. Concentrations must be expressed in molar or equivalent units (e.g., moles per later). The standard units for reporting pressure are either mmHg or cmH_2O. Virgules should be used in expressions such as "ml/kg/min"; the format "$ml \bullet kg^{-1} \bullet min^{-1}$" should not be used.

All statistical methods used must be identified and, if applicable, referenced.

Authors have final responsibility for confirming that all symbols and expressions containing superscripts or subscripts, e.g., "PaO_2", have been correctly typeset as intended.

Results:

Results should appear in logical sequence in the manuscript text, tables, and figures. Data should not be repeated unnecessarily. Emphasis should be placed only on important observations. Statistical significance should be given as values of probability.

Discussion:

New and important aspects of the study should be emphasized, with no repetition of detailed data given in the Results section. The discussion should elaborate upon the implications of the findings and their limitations and should compare these implications and limitations with those reported in other studies. All conclusions should be justifiable by the results of the study.

Acknowledgments:

Acknowledgment of individuals who assisted in the study or with manuscript preparation, including statistical review, should appear between the text and the references.

References:

Reference citations in the manuscript text must be enclosed in brackets, e.g., [1–7], [8], [2, 5–9], and must be numbered consecutively in the order cited. Accuracy of reference data is the authors' responsibility. References should be restricted to those that have direct bearing on the work described.

Articles published without peer review, including material appearing in programs of meetings or in organizational publications, should not be included in the references.

Any references to published abstracts must be less than five years old. All abstracts included in the references must be written in English. Abstracts in Japanese and

other non-English languages cannot be listed as references. Manuscripts submitted for publication are not acceptable as references, but manuscripts accepted for publication may be included in the reference list and should be marked “in press.” Personal communications and unpublished data should be cited in parentheses in the manuscript text. If a citation of this kind is from someone other than the authors, a letter must be submitted in which the direct quotation is given with the author’s signature. Sites on the World Wide Web (URLs) may not be used as references.

The journal uses the Vancouver style for references. Each journal reference should consist of the names of all authors (do not use “et al.”), title of article, journal name abbreviated according to Index Medicus, year of publication, volume number, and inclusive page numbers. For references published in Japanese with an English abstract, follow example 2 below.

For references published in Japanese, see example 3. For references published online, see example 4. Book references must include the name and location of the publisher (see example 5).

1. Keenan RL, Shapiro JH, Kane FR, Simpson PM. Bradycardia during anaesthesia in infants. An epidemiological study. Anaesthesiology. 1994;80:976–82.

2. Kanemaru T, Ogawa S, Kato J, Saeki S. Suppressive effect of sevoflurane on somatosympathetic reflexes in cats (in Japanese with English abstract). Masui (Jpn J Anesthesiol). 1992;41:1371–84.

3. Tsuneto S, Hayashi A, Yamamoto K, Kashiwagi T. Survival time from the onset of cancer pain (in Japanese). Pein Kurinikku (Pain Clinic). 1992;13:509–11.

4. Mitchell AJ, Vaze A, Rao S. Clinical diagnosis of depression in primary care: a meta-analysis. Lancet. 2009. doi: 10.1016/S0140-6736(09)60879-5.

5. Feldman S. Neuromuscular blocking drugs. In: Churchill-Davidson HC, editor. A practice of anaesthesia. Philadelphia: WB Saunders; 1979. p.898–9.

Figure legends:

Figure legends must be numbered consecutively and must define all abbreviations and symbols appearing on the figures described. Figure parts should be identified by lowercase roman letters (a, b, etc.). If illustrations are supplied with uppercase labelling, lowercase letters will still be used in the figure legends and citations. Figure titles should not be included in photographs.

Figure legends should be included in the manuscript text and not in the figure file.

Tables:

Tables must be cited in the manuscript text. Each table must be numbered and given a brief, informative title as well as footnotes, if necessary. If more than one page is used, column headings should be repeated on every page. The title and any footnotes should be on the same page as the table.

All abbreviations used must be defined in the footnotes.

If the table contains data from another published source, written permission from both the author and publisher must be submitted (as is required in the case of figures).

Footnotes to tables should be indicated by superscript lowercase letters (or asterisks for significance values and other statistical data) and included beneath the table body.

Figures:

Figures must be cited in the manuscript text and be numbered consecutively using Arabic numerals and given titles. Please prepare figures in an electronic format according to Artwork Guidelines provided toward the end of this document. Submission of previously published figures should be avoided.

If such figures are used, they must be accompanied by an acknowledgment of the source and permission from both the author and publisher of the original. The source must also be included in the list of references. Colour figures will be accepted; online

publication of colour illustrations is free of charge. For colour in the print version, however, the author will be required to cover the cost (€950 per article). Otherwise, the figures will be printed in black and white. Please note that, in such cases, it is the authors' responsibility to prepare figures to be illustrative enough to convey the necessary information even after they are converted into black and white.

Electronic Supplementary Material

Electronic supplementary material will be published in the online version only.

It may consist of

- Information that cannot be printed: animations, video clips, sound recordings
- Information that is more convenient in electronic form: sequences, spectral data, etc.
- Large original data, e.g., additional tables, illustrations, etc.

Submission

- Supply all supplementary material in standard file formats.
- Please include in each file the following information: article title, journal name, author names; affiliation and e-mail address of the corresponding author.
- To accommodate user downloads, please keep in mind that larger-sized files may require very long download times and that some users may experience other problems during downloading.

Ethical Responsibilities of Authors

This journal is committed to upholding the integrity of the scientific record. As a member of the Committee on Publication Ethics (COPE) the journal will follow the COPE guidelines on how to deal with potential acts of misconduct.

Authors should refrain from misrepresenting research results which could damage the trust in the journal, the professionalism of scientific authorship, and ultimately the entire scientific endeavour. Maintaining integrity of the research and its

presentation is helped by following the rules of good scientific practice, which include*:

The manuscript should not be submitted to more than one journal for simultaneous consideration.

The submitted work should be original and should not have been published elsewhere in any form or language (partially or in full) unless the new work concerns an expansion of previous work. (Please provide transparency on the re-use of material to avoid the concerns about text-recycling ('self-plagiarism').

A single study should not be split up into several parts to increase the quantity of submissions and submitted to various journals or to one journal over time (i.e., 'salami-slicing/publishing').

Concurrent or secondary publication is sometimes justifiable, provided certain conditions are met. Examples include translations or a manuscript that is intended for a different group of readers.

Results should be presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation (including image-based manipulation). Authors should adhere to discipline-specific rules for acquiring, selecting, and processing data.

No data, text, or theories by others are presented as if they were the author's own ('plagiarism'). Proper acknowledgements to other works must be given (this includes material that is closely copied (near verbatim), summarized and/or paraphrased), quotation marks (to indicate words taken from another source) are used for verbatim copying of material, and permissions secured for material that is copyrighted.

Important note: the journal may use software to screen for plagiarism.

Authors should make sure they have permissions for the use of software, questionnaires/(web) surveys and scales in their studies (if appropriate).

Research articles and non-research articles (e.g., Opinion, Review, and Commentary articles) must cite appropriate and relevant literature in support of the

claims made. Excessive and inappropriate self-citation or coordinated efforts among several authors to collectively self-cite is strongly discouraged.

Authors should avoid untrue statements about an entity (who can be an individual person or a company) or descriptions of their behaviour or actions that could potentially be seen as personal attacks or allegations about that person.

Research that may be misapplied to pose a threat to public health or national security should be clearly identified in the manuscript (e.g., dual use of research). Examples include creation of harmful consequences of biological agents or toxins, disruption of immunity of vaccines, unusual hazards in the use of chemicals, weaponization of research/technology (amongst others).

Authors are strongly advised to ensure the author group, the Corresponding Author, and the order of authors are all correct at submission. Adding and/or deleting authors during the revision stages is generally not permitted, but in some cases may be warranted. Reasons for changes in authorship should be explained in detail. Please note that changes to authorship cannot be made after acceptance of a manuscript.

*All the above are guidelines and authors need to make sure to respect third parties' rights such as copyright and/or moral rights.

Upon request authors should be prepared to send relevant documentation or data to verify the validity of the results presented. This could be in the form of raw data, samples, records, etc. Sensitive information in the form of confidential or proprietary data is excluded.

If there is suspicion of misbehaviour or alleged fraud the Journal and/or Publisher will carry out an investigation following COPE guidelines. If, after investigation, there are valid concerns, the author(s) concerned will be contacted under their given e-mail address and given an opportunity to address the issue. Depending on the situation, this may result in the Journal's and/or Publisher's implementation of the following measures, including, but not limited to:

If the manuscript is still under consideration, it may be rejected and returned to the author.

If the article has already been published online, depending on the nature and severity of the infraction:

- an erratum/correction may be placed with the article

- an expression of concern may be placed with the article

- or in severe cases retraction of the article may occur.

The reason will be given in the published erratum/correction, expression of concern or retraction note. Please note that retraction means that the article is **maintained on the platform**, watermarked “retracted” and the explanation for the retraction is provided in a note linked to the watermarked article.

The author’s institution may be informed

A notice of suspected transgression of ethical standards in the peer review system may be included as part of the author’s and article’s bibliographic record.

Fundamental errors

Authors have an obligation to correct mistakes once they discover a significant error or inaccuracy in their published article. The author(s) is/are requested to contact the journal and explain in what sense the error is impacting the article. A decision on how to correct the literature will depend on the nature of the error. This may be a correction or retraction. The retraction note should provide transparency which parts of the article are impacted by the error.

Suggesting / excluding reviewers

Authors are welcome to suggest suitable reviewers and/or request the exclusion of certain individuals when they submit their manuscripts. When suggesting reviewers, authors should make sure they are totally independent and not connected to the work in any way. It is strongly recommended to suggest a mix of reviewers from

different countries and different institutions. When suggesting reviewers, the Corresponding Author must provide an institutional email address for each suggested reviewer, or, if this is not possible to include other means of verifying the identity such as a link to a personal homepage, a link to the publication record or a researcher or author ID in the submission letter. Please note that the Journal may not use the suggestions, but suggestions are appreciated and may help facilitate the peer review process.

Authorship principles

These guidelines describe authorship principles and good authorship practices to which prospective authors should adhere to.

Authorship clarified

The Journal and Publisher assume all authors agreed with the content and that all gave explicit consent to submit and that they obtained consent from the responsible authorities at the institute/organization where the work has been carried out before the work is submitted.

The Publisher does not prescribe the kinds of contributions that warrant authorship. It is recommended that authors adhere to the guidelines for authorship that are applicable in their specific research field. In absence of specific guidelines, it is recommended to adhere to the following guidelines*:

All authors whose names appear on the submission

1) made substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data; or the creation of new software used in the work.
2) drafted the work or revised it critically for important intellectual content.
3) approved the version to be published; and
4) agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

* Based on/adapted from:

ICMJE, Defining the Role of Authors and Contributors,

Transparency in authors' contributions and responsibilities to promote integrity in scientific publication, McNutt at all, PNAS February 27, 2018

Disclosures and declarations

All authors are requested to include information regarding sources of funding, financial or non-financial interests, study-specific approval by the appropriate ethics committee for research involving humans and/or animals, informed consent if the research involved human participants, and a statement on welfare of animals if the research involved animals (as appropriate).

The decision whether such information should be included is not only dependent on the scope of the journal, but also the scope of the article. Work submitted for publication may have implications for public health or general welfare and in those cases, it is the responsibility of all authors to include the appropriate disclosures and declarations.

Data transparency

All authors are requested to make sure that all data and materials as well as software application or custom code support their published claims and comply with field standards. Please note that journals may have individual policies on (sharing) research data in concordance with disciplinary norms and expectations.

Role of the Corresponding Author

One author is assigned as Corresponding Author and acts on behalf of all co-authors and ensures that questions related to the accuracy or integrity of any part of the work are appropriately addressed.

The Corresponding Author is responsible for the following requirements:

- ensuring that all listed authors have approved the manuscript before submission, including the names and order of authors.
- managing all communication between the Journal and all co-authors, before and after publication; *
- providing transparency on re-use of material and mention any unpublished material (for example manuscripts in press) included in the manuscript in a cover letter to the Editor.
- making sure disclosures, declarations, and transparency on data statements from all authors are included in the manuscript as appropriate (see above).

* The requirement of managing all communication between the journal and all co-authors during submission and proofing may be delegated to a Contact or Submitting Author. In this case, please make sure the Corresponding Author is clearly indicated in the manuscript.

Author contributions

In absence of specific instructions and in research fields where it is possible to describe discrete efforts, the Publisher recommends authors to include contribution statements in the work that specifies the contribution of every author to promote transparency. These contributions should be listed at the separate title page.

Examples of such statement(s) are shown below:

• Free text:

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by [full name], [full name] and [full name]. The first draft of the manuscript was written by [full name] and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Example: CRediT taxonomy:

• Conceptualization: [full name], …; Methodology: [full name], …; Formal analysis and investigation: [full name], …; Writing - original draft preparation: [full name, …];

Writing - review and editing: [full name], …; Funding acquisition: [full name], …; Resources: [full name], …; Supervision: [full name],

For **review articles** where discrete statements are less applicable a statement should be included who had the idea for the article, who performed the literature search and data analysis, and who drafted and/or critically revised the work.

For articles that are based primarily on the **student's dissertation or thesis**, it is recommended that the student is usually listed as principal author:

A Graduate Student's Guide to Determining Authorship Credit and Authorship Order, APA Science Student Council 2006

Affiliation

The primary affiliation for each author should be the institution where most of their work was done. If an author has subsequently moved, the current address may additionally be stated. Addresses will not be updated or changed after publication of the article.

Changes to authorship

Authors are strongly advised to ensure the correct author group, the Corresponding Author, and the order of authors at submission. Changes of authorship by adding or deleting authors, and/or changes in Corresponding Author, and/or changes in the sequence of authors are **not** accepted **after acceptance** of a manuscript.

Please note that author names will be published exactly as they appear on the accepted submission!

Please make sure that the names of all authors are present and correctly spelled, and that addresses, and affiliations are current.

Adding and/or deleting authors at revision stage are generally not permitted, but in some cases, it may be warranted. Reasons for these changes in authorship should be explained. Approval of the change during revision is at the discretion of the

Editor-in-Chief. Please note that journals may have individual policies on adding and/or deleting authors during revision stage.

Author identification

Authors are recommended to use their ORCID ID when submitting an article for consideration or acquire an ORCID ID via the submission process.

Deceased or incapacitated authors

For cases in which a co-author dies or is incapacitated during the writing, submission, or peer-review process, and the co-authors feel it is appropriate to include the author, co-authors should obtain approval from a (legal) representative which could be a direct relative.

Authorship issues or disputes

In the case of an authorship dispute during peer review or after acceptance and publication, the Journal will not be in a position to investigate or adjudicate. Authors will be asked to resolve the dispute themselves. If they are unable the Journal reserves the right to withdraw a manuscript from the editorial process or in case of a published paper raise the issue with the authors' institution(s) and abide by its guidelines.

Confidentiality

Authors should treat all communication with the Journal as confidential which includes correspondence with direct representatives from the Journal such as Editors-in-Chief and/or Handling Editors and reviewers' reports unless explicit consent has been received to share information.

Open Choice

Open Choice allows you to publish open access in more than 1850 Springer Nature journals, making your research more visible and accessible immediately on publication.

Article processing charges (APCs) vary by journal – view the full list

Benefits:

Increased researcher engagement: Open Choice enables access by anyone with an internet connection, immediately on publication.

Higher visibility and impact: In Springer hybrid journals, OA articles are accessed 4 times more often on average and cited 1.7 more times on average*.

Easy compliance with funder and institutional mandates: Many funders require open access publishing, and some take compliance into account when assessing future grant applications.

It is easy to find funding to support open access – please see our funding and support pages for more information.

*) Within the first three years of publication. Springer Nature hybrid journal OA impact analysis, 2018.

Copyright and license term – CC BY

Open Choice articles do not require transfer of copyright as the copyright remains with the author. In opting for open access, the author(s) agree to publish the article under the Creative Commons Attribution License.

Submission information

Please prepare your manuscript following the detailed Instructions for Authors for this journal.

Please make sure to provide the following information with your manuscript:

- E-mail address
- Full postal address
- Telephone and fax numbers

Chapter 3 Draft article

Retrospective case series of the anaesthetic management and outcomes of patients with Rasmussen's aneurysms at an academic hospital

Hannah Elizabeth Stuart-Clark, MBChB, DA (SA)[1]

Palesa Mogane, MBChB, DA (SA), FCA (SA), MMed[1]

Josias Padi, BSc, MBChB, FCRad D (SA)[2]

[1]Department of Anaesthesiology, Chris Hani Baragwanath Academic Hospital, University of the Witwatersrand

[2]Department of Radiology, Chris Hani Baragwanath Academic Hospital, University of the Witwatersrand

Corresponding Author

HE Stuart-Clark

Department of Anaesthesiology
Chris Hani Baragwanath Academic Hospital
26 Chris Hani Rd
Diepkloof, Soweto
Johannesburg
1860

hstuartclark@gmail.com

0834102534

Key words: Rasmussen's aneurysms, Haemoptysis, Tuberculosis, Pulmonary Artery Embolization

3.1 Abstract

Background

Tuberculosis (TB) has a high burden of disease in South Africa and a Rasmussen's aneurysm is a late complication of TB (1-5). Although rare, the risk for life-threatening complications is high (>50%) (6-9). Pulmonary artery embolization (PAE) is a highly specialised, minimally invasive technique used for the management of haemoptysis caused by a Rasmussen's aneurysm which is not commonly performed in Lower Middle-Income Countries (10). There is a paucity of information regarding anaesthetic management guidelines for these patients undergoing PAE.

The aim of this study was to describe the periprocedural anaesthetic management and outcomes of patients presenting with Rasmussen's aneurysms treated with PAE in the interventional radiology suite at Chris Hani Baragwanath Academic Hospital. The data collected will be used to establish practice guidelines for this unique subset of patients

Methods

This study was designed as a retrospective case series and arterial embolization (AE) records were collected over a 4.5-year period (January 2017 – June 2021) for evaluation. All patients identified with Rasmussen's aneurysms were included in the study and the anaesthesia charts, patient hospital ward files, records from interventional radiology, the National Health Laboratory Service, and pulmonology patient records were then interrogated.

Results

The prevalence of Rasmussen's aneurysms in patients presenting for PAE with haemoptysis at this institution was 9%. Of the sixteen patients included in the study, thirteen were male and three were female. Current or previous tuberculosis infection was noted in ten patients and five patients had a current or previous history of smoking. The median duration of the general anaesthesia procedures were 4 hours 5 minutes (interquartile range 03:03 - 05:33), with nine cases done electively and

eight done as emergencies. A total of 15 patients were intubated using double lumen endotracheal tubes and 12 patients were done with both consultant and registrar anaesthesiology coverage. Median haemoglobin was 10.5g/dl and eleven patients did not receive periprocedural blood transfusions. All patients were embolised successfully using metallic coils and were sent to a high-dependency unit post-procedure.

Conclusion

Despite the limitations, this study provides several novel insights into the prevalence and anaesthetic management of Rasmussen's aneurysms in patients presenting with haemoptysis for PAE in our setting and helped establish the need for protocolised guidelines for the management of these patients. This data also allowed for the development of a novel set of guide recommendations for the management of this unique subset of patients, which include the following: guidelines for pre-operative optimisation, invasive monitoring, anaesthesia technique and postoperative care.

3.2 Introduction

Tuberculosis (TB) has a high burden of disease in South Africa, making this an ideal setting to evaluate clinical interventions for this disease. One of the rarer complications of TB is a Rasmussen's aneurysm (RA), a peripheral pulmonary artery pseudoaneurysm occurring adjacent to a TB cavity (1-5). Rasmussen's aneurysms are rare, and most case reports describe a single case, making the quantification of their prevalence difficult. One autopsy series reported a prevalence of 4-5% while Ivkovic *et al* found an incidence of 0.25% in (1, 2, 6-8). Rasmussen's aneurysms occur late in the disease progression of TB (9). Although rare, the risk for life-threatening complications such as massive haemoptysis, pulmonary artery dissection and death is high (>50%) therefore early identification and management is essential (10-13).

The lungs have a dual blood supply, and only 10% of cases of haemoptysis are due to pulmonary artery pathology (1, 13-15). The use of arterial embolization (AE) for haemoptysis was first described in 1974 and has become the standard of care for patients with TB-induced haemoptysis (16, 17). It is a minimally invasive technique which improves mortality in massive haemoptysis to 13-17.8% and has a success rate of approximately 90% (7, 15, 18-20). Rasmussen's aneurysms are treated with pulmonary artery embolization (PAE) which takes place in the interventional radiology suite (IR Suite), and thus falls under the domain of non-operating room anaesthesia (NORA) (21, 22). The rapid expansion of interventional radiology in the last decade has produced a growing demand for anaesthesia support (21, 23-25). However, NORA in the IR suite can present the anaesthesiologist with several challenges which can hinder the provision of safe anaesthetic care and protocolized care may help to address these (21, 23).

Anecdotal evidence suggests that clinicians at the IR suite at Chris Hani Baragwanath Academic Hospital (CHBAH) see several RA every year. Despite this, there is a paucity of information regarding the anaesthetic management of these patients within this setting.

The aim of this study was to describe the peri-procedural anaesthetic management and outcomes of patients presenting with RA and treated with PAE in the IR suite at Chris Hani Baragwanath Academic Hospital (CHBAH).

3.3 Methods

3.3.1 Study Design and Ethical Approval

This study used a retrospective case series design, and the protocol was approved by the University of Witwatersrand's Human Research and Ethics Committee (Medical) (M210717) and other relevant authorities.

3.3.2 Patient Cohort

Pulmonary artery embolization was introduced to CHBAH in January 2017 and all the AE records from the IR suite collected over a 4.5-year period, starting in January 2017 until the end of June 2021, were examined for relevance. All patients identified in the records with RA were then selected for inclusion in the study. Anaesthesia charts, patient hospital ward files, records from interventional radiology, the National Health Laboratory Service and pulmonology patient records were then interrogated. Data obtained from these medical records included the following: patient demographics, past medical history, laboratory investigations, peri-procedural anaesthesia management, interventional radiology management and peri-procedural outcomes.

3.3.3 Case Evaluation

Data was captured in a Microsoft Excel spreadsheet and analysed. Demographic data such as age, gender, race, and comorbidities are summarized in Table 3.1. Anaesthetic management and interventional radiology data are described in Table 3.2. Where possible categorical variables were expressed as percentages and numerical variables were expressed as median values with an interquartile range.

3.4 Results

Of the 211 patients presenting with haemoptysis within the IR suite at CHBAH for AE over the study period, 22 were identified with RA. Three patients were later

excluded as they were erroneously identified as RA with two of these excluded patients presenting with pseudoaneurysms of their pulmonary arteries post-penetrating chest trauma and the other diagnosed with a malignancy. The prevalence of RA in the patients presenting for AE with haemoptysis was 9%. Anaesthetic records were found for 16 of the remaining patients and one patient underwent two PAE under general anaesthesia. Anaesthetic records could not be found for three patients, and they were excluded. The sample size was 17 anaesthetic records (n=17). Patient selection is shown in Figure 3.1.

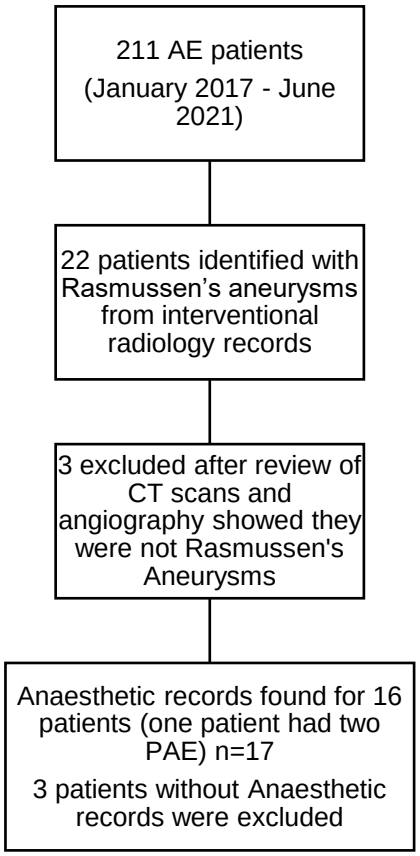


Figure 3-1: Schematic explaining the inclusion and exclusion criteria applied in this study. Arterial embolization (AE), Rasmussen's aneurysm (RA), Computerized Tomography scans (CT scans), Pulmonary artery embolization (PAE).

Of the 16 patients included in the study, thirteen were male and three were female. The median age for the cohort was 32 years and the age distribution is shown in Table 3.1. Race was only recorded for 12 of the 16 patients, with all 12 described as Black Africans.

Methods of diagnosis of RA are summarized in Table 3.1. None of the anaesthesia records noted if the patients were having active haemoptysis at the time of their PAE. Comorbidities in this cohort are listed in Table 3.1

Table 3.1: Demographic details of study participants

Age (years)	Count (Percentage) = n (%)	Median [IQR]
10-19	3 (19%)	
20-29	3 (19%)	
30-39	4 (25%)	
40-49	5 (31%)	
50-59	0 (0%)	
60-69	1 (6%)	
Median Age		32.5 [25.5 – 41.75]
Median Age Female		19 [18 – 25]
Median Age Male		34 [27 – 44]
Sex		
Female	3 (19%)	
Male	13 (81%)	
Diagnosis of Rasmussen's aneurysm		
Previous BAE	1 (6%)	
CTPA	11 (69%)	
CTPA and previous BAE	3 (19%)	
Unknown	1 (6%)	
Site of Rasmussen's aneurysm		
Left Lower	0 (0%)	

Left Upper	8 (50%)	
Right Lower	4 (25%)	
Right Upper	4 (25%)	
Tuberculosis		
Active	8 (50%)	
Previous	2 (13%)	
Sputum Negative but Positive Radiological Features	6 (38%)	
Other Respiratory Comorbidities		
Mycetoma	2 (25%)	
Necrotizing Pneumonia	1 (13%)	
Pulmonary Embolism	1 (13%)	
None	4 (50%)	
Other Comorbidities		
Arthritis	1 (5%)	
Diabetes Mellitus	2 (11%)	
Epidural Hematoma	1 (5%)	
Epilepsy	1 (5%)	
Gout	1 (5%)	
HIV	7 (37%)	
Hypertension	1 (5%)	
Meningitis	1 (5%)	
None	4 (21%)	
Smoking History		
Current	4 (25%)	
Previous	1 (6%)	
No Smoking History	11 (69%)	

(Bronchial artery embolization (BAE), Computerized Tomography Pulmonary Angiography of the Chest (CTPA), Human Immunodeficiency Virus (HIV), Interquartile Range (IQR).

One of the 16 patients underwent two PAE interventions under general anaesthesia (n=17). The urgency of the procedure, timing of cases, skill level of anaesthesia providers and distribution of the American Society of Anaesthesiologists Physical Status Classifications are summarized in Table 3.2.

The median duration of the general anaesthesia procedures was 4 hours 5 minutes (IQR 03:03 - 05:33). Of the six patients whose hospital ward files were found, all were noted to have no ongoing haemoptysis prior to their PAE after having presented with haemoptysis at admission.

Airway management technique is summarized in Table 3.2. Pre-procedural and intra-procedural transfusions are summarized in Table 3.2. Preoperative blood results and initial vitals are represented as median values with interquartile ranges in Table 3.2. All but one patient had a pre-operative INR result. None of the patients had activated partial thromboplastin time results (aPTT).

Arterial lines, central venous catheters and peripheral intravenous access is summarised in Table 3.2. One patient did not have an arterial line inserted for the procedure and only three had arterial lines inserted pre-induction. The list of complications can be found in Table 3.2. Arterial blood gas (ABG) samples were taken for fourteen of the patients, ten of whom had serial blood gas samples taken over the course of the procedure. The postoperative outcomes and destinations for the patients are summarised in Table 3.2.

All the patients had their RA embolized with metallic coils. The median radiation exposure time was 3 hours 52 minutes (interquartile range 03:16 – 05:37) and the median volume of contrast was 235 mL (interquartile range 157.5 – 300 ml).

Table 3.2: Anaesthetic management and Interventional Radiology management

Surgery type	Count (Percentage) = n (%)	Median [IQR]
Elective	9 (53%)	
Emergency	8 (47%)	
ASA Physical Status Classification		
2	3 (18%)	
3	12 (71%)	
4	2 (12%)	
Anaesthesiology Coverage		
Registrar Only	3 (18%)	
Consultant and Registrar	12 (71%)	
Consultant Only	2 (12%)	
Time of Day of Procedure		
Weekday 08:00 – 16:00	15 (88%)	
Weekday 16:00 – 08:00	1 (6%)	
Weekend	1 (6%)	
Duration of Procedure (hour : minutes)		04:05 [03:05 – 05:30]
Airway Management		
DLT	15 (88%)	
SLT	2 (12%)	
Transfusion		
Pre-procedural	4 (22%)	
Intra-procedural	3 (17%)	

None	11 (61%)	
Invasive and Peripheral Lines		
Arterial Line	16 (89%)	
CVC	6 (33%)	
Large Bore Peripheral (>18g) x1	7 (39%)	
Large Bore Peripheral (>18g) x2	8 (44%)	
Combined CVC and Large Bore Peripheral	6 (33%)	
Starting Vitals		
HR (bpm)		109 [93 – 121]
SBP (mmHg)		132 [120 – 141]
DBP (mmHg)		83 [75 – 91]
MAP (mmHg)		100 [95 – 113]
O2 Sats (%)		96 [94 – 98]
Pre-operative Blood Results		
Chloride (mmol/L)		98.5 [95.3 – 101]
Creatinine (umol/L)		67.5 [50.8 – 76.5]
Haemoglobin (g/dL)		10.5 [9.7 – 11.9]
INR		1.22 [1.12 – 1.33]
Potassium (mmol/L)		4.2 [3.9 – 4.7]
Platelet Count (x 10^9/L)		393 [254 – 567]
Sodium (mmol/L)		138 [136 – 139]
Urea (mmol/L)		3.2 [2.8 – 5.5]
Arterial Blood Gas		
Yes	14 (82%)	
No	3 (18%)	
Serial	10 (59)	
ABG Haemoglobin		10.3 [8.9 – 11]

Complications		
Adrenaline	2 (12%)	
Aneurysm Rupture	1 (6%)	
Arrhythmia	2 (12%)	
Bronchial Lavage	3 (18%)	
Delayed Emergence	1 (6%)	
Difficult Ventilation	3 (18%)	
Endotracheal Tube blocked with clot	2 (12%)	
Nil	10 (59%)	
Postoperative Destination		
Extubated (Intensive Care Unit)	1 (6%)	
Intubated (Intensive Care Unit)	1 (6%)	
Extubated (Medical High Care Unit)	14 (82%)	
Intubated (Medical High Care Unit)	1 (6%)	
Interventional Radiology Management		
Exposure Time (hour : minute)		03:52 [03:16 – 05:37]
Contrast Volume (mL)		235.00 [157.5 – 300]
Skin Dose Radiation (mGray)		540.5 [447.3 – 931.5]

American Society of Anaesthesiologists Physical Status Classification (ASA), Double Lumen Endotracheal Tube (DLT), Single Lumen Endotracheal Tube (SLT), Central Venous Catheter (CVC), Heart rate (HR), Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), Mean Arterial Blood Pressure (MAP), Oxygen saturation (O2 Sats), Haemoglobin (Hb), International normalized ration (INR), Arterial Blood Gas (ABG), Interquartile Rand (IQR).

Hospital ward files were found for only six of the patients in the records department at Chris Hani Baragwanath Academic Hospital. Loss of records, clerical errors with duplicate file numbers and patients treated as outpatients were some of the reasons behind the absence of the hospital ward files. The pulmonology database only had

details for seven of the patients identified with RA who had anaesthesia records, one of which was noted to have passed away two days after his PAE. In terms of 7-day mortality, the hospital admission electronic database recorded no deaths for the other fifteen patients and of the six patients whose hospital ward files were found, none reported haemoptysis post-PAE. In addition, six of the seven patients recorded in the pulmonology database were discharged without any complications noted.

3.5 Discussion

Rasmussen's aneurysms are rare with a prevalence ranging from between 0.25% to 4-5% in patients with TB (7, 8). We recorded a prevalence of 9% for this complication in patients presenting to our IR suite with haemoptysis. The gender distribution in our cohort was 81% male and 19% female. Ivkovic *et al.,* reported the following gender distribution in their cohort of RA, 55.6% were male and 44.33% were female (8). Gauteng's National Institute for Communicable Diseases (NICD) TB prevalence data for 2018 shows a higher prevalence of TB infections in males in the age cohort of 25 years or older compared to females, whereas there is higher prevalence in females compared to males for the age cohort of 15 to 24 years (26). The median age of the three females in the study cohort was 19 years (17, 19 and 31 years respectively) and the median age for the 13 males in the study was 34 years. This follows the trend suggested by the NICD data for TB, however further screening of patients with TB for RA in our setting may help to determine if RA are more prevalent in males. Understanding the prevalence of RA will assist with the identification of cases, thus allowing for early intervention and prevention of morbidity and mortality. Further investigation would be necessary to establish true prevalence rates for South Africa.

Seven of the sixteen patients presented with Human Immunodeficiency Virus (HIV), which is associated with an increased risk for cardiovascular disease and the development of arterial aneurysms (27). Patients with HIV and active TB are more likely to present with haemoptysis (7). Tuberculosis is often the initial presentation of an underlying HIV infection (28). It is not known if HIV is an independent risk factor for the development of RA and it is postulated that HIV may play a role in recurrent haemoptysis post-BAE (29). Further investigation would be needed to evaluate the role HIV plays in the development of RA.

A history of current or previous smoking in five of the sixteen patients was noted. Smoking is known to increase the risk of cardiovascular disease, especially the risk of developing abdominal aortic aneurysms and intracranial aneurysms (30, 31). Smokers are also more likely to develop cryptogenic massive haemoptysis (22). It is not known if smoking increases the risk of developing a RA and further investigation is warranted.

The method of choice for PAE used in the IR suite at CHBAH is embolization via coiling. Other embolization techniques include the insertion of a gelatin sponge, N-butyl cyanoacrylate (NBCA) glue injection and stent insertion (17, 32). Literature evaluating PAE techniques advocate for the use of NBCA as it is administered as a liquid and can thus block both the aneurysm and its inflow and outflow arteries (17). There is also less risk of aneurysmal rupture with NBCA glue, but its success is operator-dependent and its behaviour can be unpredictable (17). Arif *et al*., suggest that coil embolization should preferentially be used as an emergency intervention to prevent mortality (33). Coils also provide more proximal occlusion compared to the other techniques and are therefore the method of choice for embolization of pseudoaneurysms such as RA (16). However the placement of the metallic coil proximally may inhibit further embolization attempts if rebleeding occurs (34).

Occlusion of the proximal aspect of a RA often fails to address associated collateral flow (34). This can present as recurrent haemoptysis post successful PAE. Data on the efficacy of coil embolization is limited and historic for Bronchial artery embolization, however it is the recommended technique employed for the embolization of pulmonary artery aneurysms (9, 34-36). There is an increased risk of aneurysmal rupture with the use of metallic coils and care must be taken during placement to avoid overpacking the aneurysm or advancing either the catheter or coil through the aneurysmal wall (36).

Most patients had no complications during their PAE, but two patients did require an adrenaline infusion to support their haemodynamics during their PAE, one of whom was the patient where the aneurysm ruptured during the PAE. Three patients had reported difficulty with ventilation on their anaesthetic records during the procedure, two of which were reported to have a clot blocking their endotracheal tube on extubation. Two of the patients developed an arrhythmia during guidewire

placement prior to aneurysm coiling, one of whom then required adenosine and an amiodarone infusion. Common complications of AE reported in the literature include re-canalization of embolized arteries, incomplete embolization of existing arteries, development of collateral blood supply, inadvertent rupture of the aneurysm or arterial dissection, transient chest pain or back pain and dysphagia (15, 16, 32, 37). The most severe complication is spinal cord ischemia secondary to embolization of the anterior spinal arteries (15). This severe complication was not reported in any of the patients in this study.

The Society of Interventional Radiology recommend that staff in the IR suite have up-to-date advanced cardiac life support certifications (38-40). The anaesthesiologist plays a role in providing cardio-respiratory support in the event of adverse events such as aneurysmal rupture and bleeding.

The determination of long-term complications post-PAE was hampered by the lack of available documentation for follow-up and thus we were unable to adequately assess outcomes which was a significant limitation of the study. Of the six patients whose hospital ward files were found, none were noted to have recurrent haemoptysis post-PAE prior to discharge. One patient underwent two PAEs under GA for ongoing haemoptysis which is consistent with the 90% success rate for PAE (7, 15, 18-20). Pulmonary artery embolization can preserve pulmonary function and improve the prognosis for patients with haemoptysis (32, 41). As such, this method is considered one of the most effective non-surgical treatments for massive haemoptysis and has become the standard of care for patients with TB-induced haemoptysis worldwide (16, 17, 42). Only one death was noted 2 days post-BAE in this patient cohort.

3.6 Recommendations for the peri-procedural anaesthetic management

Given this data we propose that the following should be used as a guideline for the anaesthetic management of patients with RA presenting for PAE:

Pre-procedural investigations and patient optimisation:

Patient preparation and optimization is essential when determining the anaesthetic management of a patient with haemoptysis requiring PAE. A multidisciplinary

approach should be followed during pre-procedural optimization (9). Pre-anaesthesia evaluation should include a thorough history, examination and appropriate investigations to identify potential risk factors and areas for further optimization (43).

Arterial embolization requires the injection of contrast medium. Renal function tests can be used as a surrogate to estimate a patient's risk for contrast-induced nephropathy (CIN) (34, 43). Serum creatinine and estimated glomerular filtration rate are used to assess renal function (43).

Pre-procedural investigations should be directed by institution-specific protocols (22, 43, 44). Patients presenting for PAE at CHBAH must have an International Normalized Ratio (INR), a full blood count, urea, electrolytes, and creatinine. It is recommended that patients presenting for PAE have an INR ≤ 1.5, an aPTT ≤1.5x control and a platelet count ≥ 50 x 10^9/L (43, 45), a normal creatinine and Glomerular Filtration Rate and a Haemoglobin ≥ 8g/dL. Our cohort of patients had a mean haemoglobin level of 10.5 g/dL (9.7 – 11.9), a mean creatinine 67.5 umol/L (50.8 – 76.5), mean INR 1.22 (1.12 – 1.33) and mean platelet count of 393 x10^9/L (50.8 – 76.5) which all met the required values according to the CHBAH protocol.

Blood transfusion

The volume of blood loss in haemoptysis can be difficult to quantify and thus the speed of bleeding, the ability of the patient to maintain their airway and expectorate blood, the presence of hemodynamic or respiratory compromise and the patient's physiological reserve are used to determine if the bleed is life-threatening (15, 46-48). The current blood transfusion guidelines from the South African Society of Anaesthesiologists advocate for the rational use of blood products and a transfusion threshold of 7g/dL is recommended (49). Of the patients transfused during their PAE, none had a haemoglobin level of less than 7g/dL. Haemoglobin levels and the patient's hemodynamic status should be considered when using blood products in accordance with local transfusion guidelines.

Arterial embolization is a minimally invasive technique, as such detection and control of bleeding may be difficult due to lack of visualization and ability to immediately control the bleeding (43). Pulmonary artery embolization is considered

a moderate bleeding risk intervention (43, 45). Patients should have a type and screen done before the procedure in case they need transfusion, and these transfusions should be guided by institutional transfusion guidelines.

Invasive monitoring

It is important to appropriately blunt the sympathetic response to intubation and extubation in patients with RA, as excessive sympathetic stimulation can precipitate an increase in pulmonary vascular resistance which can cause right ventricular failure, aneurysmal rupture, and sudden death (50, 51). The use of invasive blood pressure monitoring provides measurement of beat-to-beat variability, which is useful in situations where rapid changes in blood pressure are anticipated, such as at intubation and extubation (51, 52). The insertion of an arterial line also allows for repetitive arterial gas sampling (52). Most of our cohort did not have pre-induction invasive blood pressure monitoring. The risk of significant complications from excessive sympathetic stimulation during intubation supports the insertion of pre-induction invasive blood pressure monitoring.

Anaesthesia technique

Arterial embolization can take between two to four hours to perform (53). General anaesthesia is the preferred technique for PAE management of RA as it provides patient immobility and controlled ventilation. This provides conditions for optimal image acquisition and delivery of treatment (38, 54, 55). Garg *et al*., advise that a minimum of two peripheral lines be inserted for any procedure being performed under general anaesthesia in the IR suite (54). Access to the patient may be limited due to the ergonomics of the IR suite, therefore extension lines and three-way taps may need to be added to the infusion lines to provide better access (25, 54).

Airway management

The use of a double lumen tube (DLT) was the method of choice for securing the airway in our cohort of patients, however no mention was made in the anaesthetic records of one lung ventilation (OLV) during these procedures. Of the two instances where a single lumen tube (SLT) was used, only one had its SLT advanced into the main stem bronchus of the unaffected side to allow for OLV and was only used as

they were unable to adequately ventilate with a DLT. In the other instance of SLT, the aneurysm ruptured, resulting in massive haemoptysis and a DLT would have had to be inserted in less-than-ideal circumstances to provide OLV and isolation.

Radchenko *et al*., advise that a large lumen SLT is faster and easier to insert than a DLT in the setting of ongoing massive haemoptysis (22). A large lumen SLT allows for the passage of a fibreoptic bronchoscope to assist in identifying the site of bleeding, provide suction and bronchial lavage and assist in the placement of a bronchial blocker or Fogarty catheter to provide OLV. An SLT can also be directed into the mainstem bronchus of the unaffected side with the assistance of a fibreoptic bronchoscope to provide OLV (22). Insertion of a DLT requires experience and a fibreoptic bronchoscope to confirm placement and may require multiple attempts to achieve the correct placement (22). A DLT's lumen is also smaller, and often only accommodates a paediatric fibreoptic bronchoscope which can be inefficient when attempting to clear clots from the airway. As none of our patient cohort had active haemoptysis at the time of their PAE, the use of a DLT to secure their airways can be supported as there would have been no urgency to secure the airway, thus allowing for the technically challenging insertion of a DLT (22).

Anaesthesia skill level

Anaesthesia in the IR suite can present multiple challenges to the anaesthesiologist (23). These include an unfamiliar location and equipment, lack of drugs or supplies, limited workspace and patient access, uncomfortable positioning of the patient, low temperature environments, and unfamiliarity with procedures and personnel (21, 23, 25). These challenges can hinder the provision of safe anaesthetic care and it is hypothesized that protocolized care may help to improve safety and patient experience (21, 23). Attentive preparation of the IR suite is essential and should be guided by the American Society of Anaesthesiologists recommendations (25).

The anaesthetic technique used depends on the anaesthesiologist's knowledge of the procedure, intraoperative and post-operative requirements (56). The most severe complication in our cohort was aneurysmal rupture requiring admission to the intensive care unit (ICU) post-procedure. The lack of consultant coverage in this case could have played a role in the patient's outcome. The technical challenges of

NORA and the technical challenges of DLT insertion mean that it is advisable to have consultant coverage to ensure optimal decision making and treatment of these patients. Further investigation would be required to determine if clinical maturity plays a role in patient outcomes.

Post operative management

It is recommended that patients be admitted to a high dependency or ICU post-procedure for close monitoring and routine post-arterial embolization care to reduce the risk of adverse outcomes such as bleeding (39, 44, 53). Where possible, the anaesthesiologist should aim to extubate the patient at the end of their PAE. Patients with RA often have poor respiratory function and have an increased risk for peri-operative respiratory complications (51). The guidelines for tracheal extubation published by the Difficult Airway Society should be followed to guide extubation in this setting (57).

3.7 Limitations

There were several limitations to this study. The main limitation was due to the rarity of RA. Limitations also arose as data collection relied on obtaining historical paper records, some of which could not be traced. Data collection also relied on the depth and accuracy of the record keeping, the standards of which varied between the anaesthesia providers, interventional radiologists, and follow-up notes by the pulmonologists. We were also unable to accurately assess outcomes and mortality due to missing records.

The lack of electronic records at CHBAH and the lack of granular data in the NICD TB database prevents calculation of comparable prevalence rates for RA in TB positive patients. The inclusion of data from other centres offering PAE in South Africa and the completion of CT scans on all patients with TB in South Africa would give a more accurate estimation of the local prevalence rates of RA. However, these improvements are beyond the scope of this case series.

3.8 Conclusion

Despite the limitations, this study still provided some insight into the prevalence of RA in patients presenting with haemoptysis for PAE in our setting. It also highlighted

that there is a clear need to develop protocolized guidelines for the anaesthetic management of these patients due to the complexity of the patient presentation, the challenges of providing an anaesthetic service in the interventional radiology suite and the risk of severe complications.

3.9 Conflict of interest

The authors have no conflicts of interest to declare.

3.10 Acknowledgement

This research was done in partial fulfilment of a Master of Medicine degree. The authors would like to thank the CHBAH Departments of Anaesthesiology, Interventional Radiology, Pulmonology and Records for their assistance in obtaining the data for this study.

3.11 References

1. Santelli ED, Katz DS, Goldschmidt AM, Thomas HA. Embolization of multiple Rasmussen aneurysms as a treatment of hemoptysis. Radiology. 1994;193(2):396-8.doi: 10.1148/radiology.193.2.7972750

2. Auerbach O. Pathology and pathogenesis of pulmonary arterial aneurysm in Tuberculous cavities. Am Rev Tuberc. 1939;39(1):99-115.doi: 10.1164/art.1939.39.1.99

3. Oriol A, Ayala Carbonero A, Sarasúa L. Hemoptisis amenazante secundaria a aneurisma de Rasmussen en paciente VIH (Life-Threatening Hemoptysis Secondary to Rasmussen's Aneurysm in an HIV Patient). Arch Bronconeumol. 2016;52:439 - 40.doi: 10.1016/j.arbr.2016.06.007

4. Nguyen ET, Silva CIS, Seely JM, Chong S, Lee KS, Müller NL. Pulmonary artery aneurysms and pseudoaneurysms in adults: Findings at CT and radiography. AJR Am J Roentgenol. 2007;188(2):W126-W34.doi: 10.2214/AJR.05.1652

5. Park HS, Chamarthy MR, Lamus D, Saboo SS, Sutphin PD, Kalva SP. Pulmonary artery aneurysms: diagnosis & endovascular therapy. Cardiovasc Diagn Ther. 2018;8(3):350-61.doi: 10.21037/cdt.2018.04.01

6. Sahoo S, Panigrahi MK, Naik S, Mohapatra PR. Rasmussen’s aneurysm masquerading as mass lesion. BMJ Case Rep. 2020;13(2):e232669.doi: 10.1136/bcr-2019-232669

7. Seedat UF, Seedat F. Post-primary pulmonary TB haemoptysis – When there is more than meets the eye. Respir Med Case Rep. 2018;25:96-9.doi: 10.1016/j.rmcr.2018.07.006

8. Ivkovic S, Milosavljevic T, Ivkovic A. MDCT with angiography in Rasmussen aneurysms. Eur Respir J. 2014;44(Suppl 58):P2631

9. Pelage J-P, Hajjam ME, Lagrange C, Chinet T, Vieillard-Baron A, Chagnon S, et al. Pulmonary Artery Interventions: An Overview. Radiographics. 2005;25(6):1653-67.doi: 10.1148/rg.256055516

10. Sapra R, Sharma G, Minz AK. Rasmussen's aneurysm: A rare and forgotten cause of hemoptysis. Indian Heart J. 2015;67:S53-S6.doi: 10.1016/j.ihj.2015.07.009

11. Gupta M, Agrawal A, Iakovou A, Cohen S, Shah R, Talwar A. Pulmonary artery aneurysm: a review. Pulm Circ. 2020;10(1):2045894020908780.doi: 10.1177/2045894020908780

12. Chatterjee K, Colaco B, Colaco C, Hellman M, Meena N. Rasmussen's aneurysm: A forgotten scourge. Respir Med Case Rep. 2015;16:74-6.doi: 10.1016/j.rmcr.2015.08.003

13. Shih S-Y, Tsai IC, Chang Y-T, Tsan Y-T, Hu S-Y. Fatal haemoptysis caused by a ruptured Rasmussen's aneurysm. Thorax. 2011;66(6):553.doi: 10.1136/thx.2010.135616

14. Khalil A, Parrot A, Nedelcu C, Fartoukh M, Marsault C, Carette MF. Severe hemoptysis of pulmonary arterial origin: signs and role of multidetector row CT angiography. Chest. 2008;133(1):212-9.doi: 10.1378/chest.07-1159

15. Davidson K, Shojaee S. Managing massive hemoptysis. Chest. 2020;157(1):77-88.doi: 10.1016/j.chest.2019.07.012

16. Panda A, Bhalla AS, Goyal A. Bronchial artery embolization in hemoptysis: a systematic review. Diagn Interv Radiol. 2017;23(4):307-17.doi: 10.5152/dir.2017.16454

17. Ugajin A, Fujii H, Nakamura H, Fujita A, Sasaki T, Mato N, et al. Transcatheter proximal coil blocking with n-Butyl-2-Cyanoacrylate injection via the pulmonary artery alone for Rasmussen’s aneurysm. Case Rep Radiol. 2019;2019:1725238.doi: 10.1155/2019/1725238

18. Lee BR, Yu JY, Ban HJ, Oh IJ, Kim KS, Kwon YS, et al. Analysis of patients with hemoptysis in a tertiary referral hospital. Tuberc Respir Dis. 2012;73(2):107-14.doi: 10.4046/trd.2012.73.2.107

19. Ong T-H, Eng P. Massive hemoptysis requiring intensive care. Intensive Care Med. 2003;29(2):317-20.doi: 10.1007/s00134-002-1553-6

20. Reechaipichitkul W, Latong S. Etiology and treatment outcomes of massive hemoptysis. Southeast Asian J Trop Med Public Health. 2005;36(2):474-80.PMID: 15916059

21. Chang B, Kaye AD, Diaz JH, Westlake B, Dutton RP, Urman RD. Interventional procedures outside of the operating room: Results from the National Anesthesia Clinical Outcomes Registry. J Patient Saf. 2018;14(1):9-16.doi: 10.1097/pts.0000000000000156

22. Radchenko C, Alraiyes AH, Shojaee S. A systematic approach to the management of massive hemoptysis. J Thorac Dis. 2017:S1069-S86.doi: 10.21037/jtd.2017.06.41

23. Amin A, Lane JS. The future of anesthesia for interventional radiology. Curr Opin Anaesthesiol. 2018;31(4):469-72.doi: 10.1097/aco.0000000000000609

24. Vari A, Gangi A. Anesthesia practices for interventional radiology in Europe. Cardiovasc Intervent Radiol. 2017;40(6):803-13.doi: 10.1007/s00270-017-1576-6

25. Azizad O, Joshi G. Overview of anesthesia for interventional radiology Waltham, (MA): UpToDate.com; 2019 [updated 19 August 2019; cited 2021 17 February]. Available from: https://www.uptodate.com/contents/overview-of-anesthesia-for-interventional-radiology-procedures?search=anaesthesia%20interventional%20radiology&source=search_result&selectedTitle=1~150&usage_type=default&display_rank=1.

26. National Institute for Communicable Diseases. Microbiologically confirmed tuberculosis 2004 -15, South Africa. In: Service NHL, editor. South Africa: NICD; 2017.

27. Kariyanna PT, Yager J, Salciccioli L, Lazar JM, Polman DJ, Chandrakumar HP, et al. HIV-associated extracranial arterial aneurysms: A systematic review. Am J Med Case Rep. 2020;8(5):128-33.doi: 10.12697/ajmcr-8-5-5

28. Getahun H, Kittikraisak W, Heilig CM, Corbett EL, Ayles H, Cain KP, et al. Development of a Standardized Screening Rule for Tuberculosis in People Living with HIV in Resource-Constrained Settings: Individual Participant Data Meta-analysis of Observational Studies. PLoS Med. 2011;8(1):e1000391.doi: 10.1371/journal.pmed.1000391

29. Alexander GR. A retrospective review comparing the treatment outcomes of emergency lung resection for massive haemoptysis with and without preoperative bronchial artery embolization. Eur J Cardiothorac Surg. 2013;45(2):251-5.doi: 10.1093/ejcts/ezt336

30. Aune D, Schlesinger S, Norat T, Riboli E. Tobacco smoking and the risk of abdominal aortic aneurysm: a systematic review and meta-analysis of prospective studies. Sci Rep. 2018;8(1):14786-.doi: 10.1038/s41598-018-32100-2

31. Ogilvy CS, Gomez-Paz S, Kicielinski KP, Salem MM, Akamatsu Y, Waqas M, et al. Cigarette smoking and risk of intracranial aneurysms in middle-aged women. J Neurol Neurosurg Psychiatry. 2020;91(9):985.doi: 10.1136/jnnp-2020-323753

32. Harmon TS, Kaleka G, Maciolek LM, Kathuria MK, Gill GS, Hussain A, et al. Becoming the standard: Expanding the conventional use of interventional embolization for ruptured pulmonary artery aneurysms. Cureus. 2018;10(11):e3576-e.doi: 10.7759/cureus.3576

33. Arif A, Bhinder KK, Sarfraz A, Sarfraz Z, Felix M, Chérrez-Ojeda I. The radiological presentation of Rasmussen aneurysm secondary to pulmonary tuberculosis and COVID-19: A case report. Radiol Case Rep. 2021;16(11):3350-3.https://doi.org/10.1016/j.radcr.2021.07.088

34. Sopko DR, Smith TP. Bronchial artery embolization for hemoptysis. Semin Intervent Radiol. 2011;28(1):48-62.doi: 10.1055/s-0031-1273940

35. Chen Y, Gilman MD, Humphrey KL, Salazar GM, Sharma A, Muniappan A, et al. Pulmonary Artery Pseudoaneurysms: Clinical Features and CT Findings. AJR Am J Roentgenol. 2017;208(1):84-91.doi: 10.2214/ajr.16.16312

36. Parakh R, Gupta K, Yadav A, Grover T, Satwik A, Agarwal S. Endovascular treatment for peripheral pulmonary artery aneurysm. Vascular. 2010;18(1):37-40.doi: 10.2310/6670.2009.00056

37. Ianniello A, Carrafiello G, Nicotera P, Vaghi A, Cazzulani A. Endovascular treatment of a ruptured pulmonary artery aneurysm in a patient with Behçet's disease using the Amplatzer Vascular Plug 4. Korean J Radiol. 2013;14(2):283-6.doi: 10.3348/kjr.2013.14.2.283

38. Schenker MP, Martin R, Shyn PB, Baum RA. Interventional Radiology and Anesthesia. Anesthesiol Clin. 2009;27(1):87-94.doi: 10.1016/j.anclin.2008.10.012

39. Martin ML, Lennox PH. Sedation and Analgesia in the Interventional Radiology Department. J Vasc Interv Radiol. 2003;14(9):1119-28.doi: 10.1097/01.RVI.0000086536.86489.82

40. Baerlocher MO, Kennedy SA, Ward TJ, Nikolic B, Bakal CW, Lewis CA, et al. Society of Interventional Radiology Position Statement: Staffing Guidelines for the Interventional Radiology Suite. J Vasc Interv Radiol. 2016;27(5):618-22.doi: 10.1016/j.jvir.2016.02.010

41. Matsumura Y, Shiono S, Saito K, Sato T. Pulmonary artery pseudoaneurysm after lung resection successfully treated by coil embolization. Interact Cardiovasc Thorac Surg. 2010;11(3):364-5.doi: 10.1510/icvts.2010.236661

42. Zhang Y, Chen C, Jiang G-n. Surgery of massive hemoptysis in pulmonary tuberculosis: Immediate and long-term outcomes. J Thorac Cardiovasc Surg. 2014;148(2):651-6.doi: 10.1016/j.jtcvs.2014.01.008

43. Taslakian B, Georges Sebaaly M, Al-Kutoubi A. Patient Evaluation and Preparation in Vascular and Interventional Radiology: What Every Interventional Radiologist Should Know (Part 1: Patient Assessment and Laboratory Tests). Cardiovasc Intervent Radiol. 2016;39(3):325-33.doi: 10.1007/s00270-015-1228-7

44. Kandarpa K, Machan L, Durham J. Handbook of Interventional Radiologic Procedures. Hagerstown, UNITED STATES: Wolters Kluwer; 2016.

45. Kohi MP, Fidelman N, Behr S, Taylor AG, Kolli K, Conrad M, et al. Periprocedural Patient Care. RadioGraphics. 2015;35(6):1766-78.doi: 10.1148/rg.2015150038

46. Ibrahim WH. Massive haemoptysis: the definition should be revised. Eur Respir J. 2008;32(4):1131.doi: 10.1183/09031936.00080108

47. Heijkoop B, Gillespie H, Kiroff G. Emergency management of massive haemoptysis. BMJ Case Rep. 2019;12(1).doi: 10.1136/bcr-2018-225620

48. Chandra AS, Rajalingam K, V. KBR, Prasad PK. A study of lung resection for haemoptysis with or without pre-operative bronchial artery embolisation. Int Surg J. 2016;3(3):5.doi: 10.18203/2349-2902.isj20162709

49. Wise R, Bishop D, Gibbs M, Govender K, James M, Kabambi F, et al. South African Society of Anaesthesiologists perioperative patient blood management guidelines 2020 South Africa: SASA; 2020 [cited 2021 1 November]. Available from: https://sasaapi.sasaweb.com/Document/PerioperativePatientBloodManagementGuidelines2020_637431060739558600.pdf.

50. Balcı E, Demir A, Özgök A, Karadeniz Ü. Anaesthesia management in idiopathic pulmonary artery aneurysm surgery. Turk J Anaesthesiol Reanim. 2019;47(6):503-6.doi: 10.5152/TJAR.2019.21447

51. Karmarkar S, Varshney S. Tracheal extubation. BJA Educ. 2008;8(6):214-20.doi: 10.1093/bjaceaccp/mkn036

52. Ward M, Langton J. Blood pressure measurement. BJA Educ. 2007;7(4):122-6.doi: 10.1093/bjaceaccp/mkm022

53. Oxford Centre for Respiratory Medicine. Bronchial Artery Embolisation: Information for patients. In: Trust ORHN, editor.: Oxford Radcliffe Hospitals NHS Trust; 2010. p. 9-10.

54. Garg R, Pandey RM, Darlong V, Punj J. Anaesthetic considerations for Interventional Radiology. Inter J Anesthesiol. 2008;19

55. Watkinson A, Francis I, Torrie P, Platts AD. The role of anaesthesia in interventional radiology. Br J Radiol. 2002;75:105-6.doi: 10.1259/bjr.75.890.750105

56. Landrigan-Ossar M. Common procedures and strategies for anaesthesia in interventional radiology. Curr Opin Anaesthesiol. 2015;28(4):458-63.doi: 10.1097/aco.0000000000000208

57. Popat M, Mitchell V, Dravid R, Patel A, Swampillai C, Higgs A. Difficult Airway Society Guidelines for the management of tracheal extubation. Anaesthesia. 2012;67(3):318-40.doi: 10.1111/j.1365-2044.2012.07075.x

Chapter 4 Proposal

Retrospective case series of the anaesthetic management and outcomes of patients with Rasmussen's aneurysms at an academic hospital

Hannah Stuart-Clark

2062634

Supervisor	Palesa Mogane
	Department of Anaesthesiology, University of Witwatersrand
Co-supervisor	Josias Padi
	Department of Radiology, University of Witwatersrand

4.1 Introduction and problem statement

According to the World Health Organization, Tuberculosis (TB) is one of the top ten causes of mortality globally, with approximately 10 million cases identified in 2019 (1, 2). Globally, Africa accounts for 25% of annual cases of TB, and the incidence in South Africa is approximately 615 per 100 000 (1, 3). The incidence of TB in South Africa, and globally, has been decreasing, but it still carries a significant public health burden, especially in developing countries (2). The emergence of the Covid-19 pandemic in 2019 has led to concern that the gains made in reducing the burden of disease of TB may regress due to the reallocation of resources (1, 4).

The clinical manifestations of *Mycobacterium tuberculosis* infection can be varied, with pulmonary disease affecting the lung parenchyma, pleura, airways and vascular structures (4, 5). Eight percent of patients may present with haemoptysis which can range from mild to life-threatening, with mortality ranging from 5-25% (5, 6). In developing countries, TB is the leading cause of haemoptysis (7-10). Haemoptysis in TB can occur in patients with active infection or in patients who are post-TB therapy (11). Inflammation and hypoxia incites the propagation of blood vessels in response to the release of vascular endothelial growth factor and angiopoietin-1 (10). New blood vessels tend to be thin-walled and prone to rupture (10). Proangiogenic factors affect both the bronchial and pulmonary artery supplies (5, 10, 12, 13). Patients who are post-TB therapy have distortion of their lung parenchyma with altered vasculature which is prone to rupture and cause haemoptysis (11).

Minor haemoptysis in active TB is usually self-limiting and often responds to conventional TB therapy (14). Massive haemoptysis in TB occurs due to chronic parenchymal disease. It is an uncommon, but life-threatening complication (10, 14, 15). Massive haemoptysis has a high mortality rate, with more than 75% of patients demising if conservatively managed (9, 10, 15, 16). Massive haemoptysis is challenging to manage and requires aggressive measures to elicit cause and initiate prompt therapy (9). Mortality in massive haemoptysis occurs due to aspiration of blood resulting in asphyxiation, severe hypoxaemia, and hypotension (7, 9, 17, 18). The lungs have a dual blood supply. Ninety percent of cases presenting with

haemoptysis arise from bronchial artery bleeds and 10% arise from pulmonary artery aneurysms, 5% of which are due to Rasmussen's aneurysms (10, 16, 19, 20).

Rasmussen's aneurysms were first identified by Fritz Valdemar Rasmussen in 1868 in a series of autopsies conducted on patients who had TB with haemoptysis (2, 11, 15, 20-24). Traditionally, a Rasmussen's aneurysm is defined as a pseudoaneurysm of a peripheral pulmonary artery which is adjacent to a TB cavity, and typically occurs in the upper lobes of the lung (15, 20, 21, 25, 26). However, it now has a wider definition and includes all aneurysms or pseudoaneurysms involving pulmonary arteries in the presence of a disease which causes destruction of pulmonary parenchyma, such as Behçet's disease (15, 20, 21, 25, 27). Granulomatous infiltration of arterial walls results in vascular remodelling due to fibrin deposits and caseation which results in progressive weakening of the vessel causing dilatation (11, 28, 29).

Rasmussen's aneurysms are rare, and case reports in the literature usually report on single cases. They have a reported prevalence of 5% in autopsy series (30). Ivkovic et al screened 21 532 patients with TB using multidetector computed tomography angiography and found 54 patients with Rasmussen's aneurysms (0.25% incidence) (31). The exact incidence of Rasmussen's aneurysms has not been reported (32). Although rare, the risk for life-threatening complications such as massive haemoptysis or pulmonary artery dissection is high therefore early identification and management is essential (23, 33). The gold standard for investigation is a computed tomography angiogram as it provides anatomical information about the Rasmussen's aneurysm, identifies potential causes and guides management (15, 26). However, Rasmussen's aneurysms are not routinely looked for and can be missed on computed tomography pulmonary angiogram (CTPA) (23).

Patients with massive haemoptysis tend to be poor surgical candidates with reduced respiratory reserve and are at high risk for post-operative complications such as persistent air leaks, bronchopulmonary fistulae, and coagulopathy (34, 35). This is further complicated by the lack of clear guidelines for perioperative anaesthetic management of these patients (35). The advantage of surgical management is that it provides definitive treatment of massive haemoptysis because it removes the

source of bleeding (35). Surgery in these high-risk patients is associated with mortality rates of 7.1-18.2% which increases to 40-50% if surgery is done in the emergent setting (5, 12, 36-38). Surgical adverse outcomes are associated with advanced age, pleural adhesions, pneumonectomy and bronchiectasis (39).

The use of bronchial artery embolization (BAE) in haemoptysis was first described in 1974 and it has become the standard of care for patients with TB-induced haemoptysis who are considered too high risk for surgery (40, 41). BAE is a minimally invasive technique which improves mortality in massive haemoptysis to 13-17.8% and has a success rate of approximately 90% (10, 11, 42-44). The use of a minimally invasive techniques can save pulmonary function and improve prognosis (45, 46). It can also be used in patients with multiple aneurysms (45, 47). BAE can also act as a bridging therapy to definitive surgical management (11). BAE is one of the most effective non-surgical treatments for massive haemoptysis (35). Traditionally, the interventional radiologist will start with an evaluation of the bronchial arterial system to try to locate the source of bleeding. If the source of bleeding cannot be identified, a systematic and sequential review of the pulmonary and systematic circulation will be conducted to try locate the source (48). This is recommended in order to reduce the risk of rebleeding and improve control of haemoptysis (48). In a resource limited setting such as South Africa, with a high burden of disease of TB, diagnostic tools and specialist management options such as BAE may not be readily available which contributes to the high mortality of massive haemoptysis (11).

BAE typically takes place in the interventional radiology suite. This falls under the domain of non-operating room anaesthesia (NORA) (49). The field of interventional radiology has been advancing rapidly in the past few years and there is growing demand for anaesthesia support (49-52). NORA in the interventional radiology suite can present multiple challenges to the anaesthesiologist (50). These include an unfamiliar location and equipment, lack of drugs or supplies, limited workspace and patient access, uncomfortable positioning of patient, cold environment, and unfamiliarity with procedures and personnel (49, 50, 52). These challenges can hinder the provision of safe anaesthetic care and protocolised care may help to improve safety and patient experience (49, 50). The anaesthetic technique used

depends on the anaesthesiologist's knowledge of the procedure which includes the duration, possible complications, intraoperative requirements and post-operative requirements (53). Patients who are managed in interventional radiology tend to be sicker, older and with more complex than those presenting for traditional surgery (49, 53, 54).

In the setting of massive haemoptysis, initial management of the patient utilises the following advanced cardiac life support principles: secure the airway, optimise oxygenation, and stabilise the haemodynamic status (5, 9, 39, 55). This often requires the involvement of a multidisciplinary team consisting of the anaesthesiologist, interventional radiologist, and surgeon (55, 56).

Initial airway management can be achieved with a single lumen endotracheal tube until the site of bleeding has been identified, either via fibreoptic bronchoscopy, chest computed tomography or bronchial artery embolization (9, 39). Once the site of the bleed has been identified, lung isolation can be achieved through a tube exchange with a double-lumen endotracheal tube, use of a bronchial blocker or advancement of the single-lumen endotracheal tube into the main bronchus of the unaffected side (9). The patient should then be positioned with the bleeding side in the dependent position to optimise oxygenation of the unaffected lung (55).

BAE will provide immediate control of a bleed in 75-90% of patients (9). The type of anaesthetic technique and fluid management choice is dependent on the patient's condition (52, 53, 56). Anaesthetic techniques which can be used include sedation with monitored anaesthesia care, regional or neuraxial techniques or general anaesthesia (52). As mentioned above, massive haemoptysis often necessitates the use of lung isolation techniques (53). Patients may also require massive transfusion, inotropic support, and invasive monitoring (53, 55). In patients with mild haemoptysis or those who are stable, the management options are more unclear and there is a general paucity of literature regarding the anaesthetic approach for these patients (53). As such, patients with haemoptysis presenting to interventional radiology are a unique anaesthetic challenge (53).

Rasmussen's aneurysms are rare, as such there is a paucity of data with regards to anaesthetic management of these patients in the interventional radiology suite. As

mentioned, the growing popularity of minimally invasive techniques such as BAE means that anaesthesia support in the interventional radiology suit is becoming more frequent. There are currently no clear or definitive therapeutic guidelines for the management of patients with Rasmussen's aneurysm (57, 58).

4.2 Aim and objectives

4.2.1 Aim

The aim of this study is to describe the periprocedural anaesthetic management and outcomes of patients presenting with Rasmussen's aneurysms to interventional radiology for BAE at Chris Hani Baragwanath Academic Hospital.

4.2.2 Objectives

The primary objectives of this study are to determine the periprocedural anaesthetic management approach used for patients undergoing interventional radiology procedures for Rasmussen's aneurysms at Chris Hani Baragwanath Academic Hospital and to use this to design a guideline for management based on the findings.

The secondary objectives of this study are to determine:

- The demographics of patients presenting to interventional radiology with Rasmussen's aneurysms
- The interventional radiology technique employed to manage the Rasmussen's aneurysm
- The outcomes of the intervention employed to manage the Rasmussen's aneurysm.

4.3 Research assumptions

The following definitions will be used in the study:

Aneurysm: focal dilatation of a blood vessel, typically arterial, which affects the intima, media, and adventitia. They can be divided into fusiform/symmetric

(dilatation involves entire circumference of the blood vessel) or saccular/asymmetric (only part of the circumference is dilated) (59, 60).

Pseudoaneurysm: also known as false aneurysms. They occur at the site of an arterial wall injury with a haematoma formation in the local tissues (20, 61).

Pulmonary artery aneurysm: focal dilatation of pulmonary artery beyond normal diameter (> 29mm main pulmonary artery and >17 mm interlobar pulmonary artery) (25, 26).

Pulmonary artery pseudoaneurysm: focal saccular dilatation of a pulmonary artery due to a contained rupture of the artery (26, 62).

Rasmussen's aneurysm: pseudoaneurysm of the pulmonary artery caused by erosion into the artery by an adjacent TB cavity (11, 20, 21, 28)

Bronchial artery aneurysm: dilatation of bronchial artery

Haemoptysis: expectoration of blood (11).

Massive haemoptysis: the expectoration of more than 600ml blood over 24 hours, or more than 250ml in a single episode, or bronchial blood loss resulting in haemodynamic or respiratory compromise (38, 63, 64).

Interventional radiology: the use of various radiological imaging techniques to diagnose diseases or injuries and the use of these to perform a range of interventional medical procedures (65).

Bronchial Artery embolization (BAE): the use of interventional radiology techniques to embolise bronchial or pulmonary artery aneurysms.

BAE Outcomes: described in terms of immediate clinical success, failure of intervention, recurrence of haemoptysis, and long term control of haemoptysis (40).

Non-operating room anaesthesia (NORA): delivery of anaesthesia by a trained anaesthesiologist in a site other than an operating theatre (49).

Haemodynamic instability: described in terms of the Haemodynamic Instability score, looking at changes in heart rate, blood pressure, volume therapy and use of vasopressor or inotropic support (66).

Morbidity: described in term of complications such as recurrence of rebleed, failure of BAE intervention, need for transfusion or inotropic support.

Mortality: the seven-day mortality post BAE intervention.

4.4 Demarcation of study field

All patients presenting to interventional radiology at Chris Hani Baragwanath Academic Hospital for BAE since the initiation of the service in January 2017 will have their records in the interventional radiology department reviewed. All patients identified with a diagnosis of a Rasmussen's aneurysm from these cases will be selected for inclusion in the study.

4.5 Ethical considerations

Approval to conduct the study will be obtained from the Human Research Ethics Committee (Medical), the Graduate Studies Committee of the University of the Witwatersrand and the Chris Hani Baragwanath Academic Hospital Medical Advisory Committee. Approval to conduct the study was obtained from the Head of Department of Anaesthesiology of the University of Witwatersrand (Appendix 1).

The study will be conducted according to the principles of the Declaration of Helsinki (67) and the South African Guidelines for Good Clinical Practice (68).

4.6 Research methodology

4.6.1 Research design

A retrospective case series design will be used in this study. Retrospective case series are useful when a rare or new disease or treatment is being described (69). Data in retrospective case series is collected after the event or activity has occurred and the outcome of these are known (70, 71). The use of existing data is quicker and has lower costs and there is no loss to follow-up (72). The data collected for a

retrospective case series can also be used to generate hypotheses which can be studied at a later stage (72).

4.6.2 Study population

The study population will consist of all the patients identified with Rasmussen's aneurysms during the period January 2017 (date of inception of the BAE service) to June 2021 in the Interventional Radiology suite at Chris Hani Baragwanath Academic Hospital.

4.6.3 Study sample

Sample size

All patients identified with Rasmussen's aneurysms presenting to the interventional radiology suite at Chris Hani Baragwanath Academic Hospital will be included in the sample. To date, an estimated 208 BAE have been performed with a minimum of 20 patients having been identified with Rasmussen's aneurysms. The sample size will be realised by the records identified and will be approximately 20-25.

Sampling method

A purposive sampling method will be used for this study. This utilises a non-probability sampling method and is based on the judgement of the researcher regarding the participants that are deemed representative of the study phenomenon, or who have knowledge regarding the question being investigated (73). Purposive sampling is also known as judgemental sampling.

All the patients presenting for BAE during the period of January 2017 to June 2021 will have their records in interventional radiology department at Chris Hani Baragwanath Academic Hospital screened. All patients identified with Rasmussen's aneurysms will be selected. The anaesthetic records, case notes from interventional radiology and the patients' hospital files will be interrogated to extract the data needed to answer the objectives of the study.

Inclusion and exclusion criteria

All cases of Rasmussen's aneurysm will be included in the study. There are no exclusion criteria.

4.6.4 Data collection

The cases identified with Rasmussen's aneurysms will be included in the study. Anaesthetic charts, interventional radiology case notes and patients' hospital files will be interrogated to extract the data required to answer the aims and objectives of this study. Data will be collated in an Excel spreadsheet

4.6.5 Data analysis

Data obtained will be captured onto a Microsoft Excel spread sheet and analysed in consultation with a biostatistician using Stata version 15 (StataCorp, USA). Descriptive statistics will be used, and categorical variables will be described using frequencies and percentages. Continuous variables will be reported using means and standard deviations or medians and interquartile ranges depending on the distribution of the data. Where appropriate, 95% confidence intervals will be reported.

4.7 Significance of the study

Although Rasmussen's aneurysms are rare, if they present with massive haemoptysis, they have a high mortality rate (9, 10, 15, 16). Minimally invasive treatment techniques for Rasmussen's aneurysms using interventional radiology are gaining popularity. There is a paucity of data with regards to anaesthetic management of these patients in the interventional radiology suite and there are currently no clear or definitive therapeutic guidelines for the anaesthetic management of patients with Rasmussen's aneurysms (57, 58). The number of patients with Rasmussen's aneurysms presenting to the interventional radiology suite at Chris Hani Baragwanath Academic Hospital provides us with a unique opportunity to study a cohort of these patients, which are usually represented in the literature as individual case reports. The results of this study should provide us the opportunity to explore our unique burden of disease to provide insight into the anaesthetic management techniques used for patients with Rasmussen's

aneurysms as well provide demographic information and outcomes of the interventions.

4.8 Validity and reliability of the study

Validity refers to the extent to which a measurement represents a true value and reliability elicits the consistency of the measurements (70).

Validity and reliability of this study will be achieved by the following:

- using an appropriate study design.
- identification of cases with Rasmussen's aneurysms done by the Interventional Radiology Suite at Chris Hani Baragwanath Academic Hospital and review of their case notes and anaesthetic charts.
- analysing the data in consultation with a biostatistician.

There are two potential areas where validity may be compromised by utilising a retrospective case study design, these include "recall effect" and "spoiler effect" (70, 72). The "recall effect" occurs due to imperfect recollection of facts or poor clinical note taking when reviewing charts (70). One way to limit bias due to recall is to identify hard facts (70). This can be achieved by reviewing the case notes and anaesthetic charts of the cases identified with Rasmussen's aneurysms. The "spoiler effect" arises from inadvertent skewing of data in the presence of prior knowledge (70). This can result in inadvertent exaggeration of data to support a hypothesis or under-exaggeration of poor, inconsistent data (70). As Rasmussen's aneurysms are rare, we may inadvertently exaggerate our data because of the small sample size.

4.9 Potential limitations

There are several potential limitations to using a retrospective case study design. We are relying on being able to access historic anaesthetic charts and notes for the cases of Rasmussen's aneurysm identified by the Interventional Radiology Suite at Chris Hani Baragwanath Academic Hospital. Information recorded on these charts may be incomplete which will limit the data which can be obtained. Rasmussen's

aneurysms are rare and as such case numbers may be small and the data collected may not be truly representative.

4.10 Project outline

4.10.1 Time frame

ACTIVITY	Jan 2021	Feb 2021	Mar 2021	Apr 2021	May 2021	June 2021	July 2021	Aug 2021	Sept 2021	Oct 2021	Nov 2021	Dec 2021
Proposal preparation												
Proposal submission												
Ethics approval												
Postgrad approval												
Data collection												
Data analysis												
Article												
Submission												

4.10.2 Budget

Item	**Number**	**Cost (R)**	**Total (R)**
Printing	1500	1	1500
Binding	2	20	40
Total			**R1540**

The cost of the paper and printing of the postgraduate application will be incurred by the Department of Anaesthesiology at the University of the Witwatersrand.

4.11 References

1. World Health Organization. Global tuberculosis report Geneva: World Health Organization; 2020 [cited 2021 1 November]. Available from: https://apps.who.int/iris/bitstream/handle/10665/336069/9789240013131-eng.pdf.

2. Giraldo-Montoya ÁM, Rodríguez-Morales AJ, Hernández-Hurtado JD, López-Salazar Á, Lagos-Grisales GJ, Ruiz-Granada VH. Rasmussen aneurysm: A rare but not gone complication of tuberculosis. Int J Infect Dis. 2018;69:8-10.doi: 10.1016/j.ijid.2018.01.023

3. World Health Organization. Tuberculosis Geneva: World Health Organisation; 2020 [cited 2020 20 December]. Available from: https://www.who.int/news-room/fact-sheets/detail/tuberculosis.

4. National Institute for Communicable Diseases. Microbiologically confirmed tuberculosis 2004 -15, South Africa. In: Service NHL, editor. South Africa: NICD; 2017.

5. Syed M, Irby J. Airway management of ruptured pulmonary artery “Rasmussen” aneurysm and massive hemoptysis. BMC Res Notes. 2015;8(1):346.doi: 10.1186/s13104-015-1313-7

6. Yoon W, Kim JK, Kim YH, Chung TW, Kang HK. Bronchial and nonbronchial systemic artery embolization for life-threatening hemoptysis: a comprehensive review. Radiographics. 2002;22(6):1395-409.doi: 10.1148/rg.226015180

7. Chung MY, Jeong H-D, Kim S-G, Kim CJ. Hemoptysis during general anesthesia in a diabetic patient with healed tuberculosis: a case report. Korean J Anesthesiol. 2017;70(1):86-9.doi: 10.4097/kjae.2017.70.1.86

8. Johnson JL. Manifestations of hemoptysis. How to manage minor, moderate, and massive bleeding. Postgrad Med. 2002;112(4):101-6, 8-9, 13.doi: 10.3810/pgm.2002.10.1335

9. Håkanson E, Konstantinov IE, Fransson SG, Svedjeholm R. Management of life-threatening haemoptysis. Br J Anaesth. 2002;88(2):291-5.doi: 10.1093/bja/88.2.291

10. Davidson K, Shojaee S. Managing massive hemoptysis. Chest. 2020;157(1):77-88.doi: 10.1016/j.chest.2019.07.012

11. Seedat UF, Seedat F. Post-primary pulmonary TB haemoptysis – When there is more than meets the eye. Respir Med Case Rep. 2018;25:96-9.doi: 10.1016/j.rmcr.2018.07.006

12. Picard C, Parrot A, Boussaud V, Lavolé A, Saidi F, Mayaud C, et al. Massive hemoptysis due to Rasmussen aneurysm: detection with helicoidal CT angiography

and successful steel coil embolization. Intensive Care Med. 2003;29(10):1837-9.doi: 10.1007/s00134-003-1912-y

13. Corr P. Pulmonary artery aneurysm as a cause of massive hemoptysis: diagnosis and management. Case Rep Radiol. 2011;2011:141563-.doi: 10.1155/2011/141563

14. Rajamannar KV, Kilaru H, Aravelly S, Gudipati AR, Kilaru SC. Massive hemoptysis from Rasmussen's aneurysm in active pulmonary tuberculosis; A case report of successful treatment with bronchial artery embolization. Respir Med Case Rep. 2017;22:277-9.doi: 10.1016/j.rmcr.2017.10.003

15. Oriol A, Ayala Carbonero A, Sarasúa L. Hemoptisis amenazante secundaria a aneurisma de Rasmussen en paciente VIH (Life-Threatening Hemoptysis Secondary to Rasmussen's Aneurysm in an HIV Patient). Arch Bronconeumol. 2016;52:439 - 40.doi: 10.1016/j.arbr.2016.06.007

16. Shih S-Y, Tsai IC, Chang Y-T, Tsan Y-T, Hu S-Y. Fatal haemoptysis caused by a ruptured Rasmussen's aneurysm. Thorax. 2011;66(6):553.doi: 10.1136/thx.2010.135616

17. Wang Y-L, Hong C-L, Chung Han S, Ho Angie CY, Yu Chi L, Liu H-P, et al. Massive hemoptysis after the initiation of positive pressure vntilation in a patient with pulmonary Tuberculosis. Anesthesiology. 2000;92(5):1480-.doi: 10.1097/00000542-200005000-00040

18. Winter SM, Ingbar DH. Massive hemoptysis: pathogenesis and management. J Intensive Care Med. 1988;3(3):171-88.doi: 10.1177/088506668800300306

19. Khalil A, Parrot A, Nedelcu C, Fartoukh M, Marsault C, Carette MF. Severe hemoptysis of pulmonary arterial origin: signs and role of multidetector row CT angiography. Chest. 2008;133(1):212-9.doi: 10.1378/chest.07-1159

20. Santelli ED, Katz DS, Goldschmidt AM, Thomas HA. Embolization of multiple Rasmussen aneurysms as a treatment of hemoptysis. Radiology. 1994;193(2):396-8.doi: 10.1148/radiology.193.2.7972750

21. Auerbach O. Pathology and pathogenesis of pulmonary arterial aneurysm in Tuberculous cavities. Am Rev Tuberc. 1939;39(1):99-115.doi: 10.1164/art.1939.39.1.99

22. Chiu H-W, Kuo S-H, Lai R-S, Wu M-T, Wu H-F. Ambiguous presentation of Mycobacterium avium complex-associated Rasmussen aneurysm. Respirol Case Rep. 2017;5(3):e00219.doi: 10.1002/rcr2.219

23. Sapra R, Sharma G, Minz AK. Rasmussen's aneurysm: A rare and forgotten cause of hemoptysis. Indian Heart J. 2015;67:S53-S6.doi: 10.1016/j.ihj.2015.07.009

24. Neelakantan S, Anandarajan R, Swamy AK. Rare cause of massive haemoptysis in pulmonary tuberculosis: Rasmussen's aneurysm. BMJ Case Rep. 2016;2016:bcr2016216652.doi: 10.1136/bcr-2016-216652

25. Nguyen ET, Silva CIS, Seely JM, Chong S, Lee KS, Müller NL. Pulmonary artery aneurysms and pseudoaneurysms in adults: Findings at CT and radiography. AJR Am J Roentgenol. 2007;188(2):W126-W34.doi: 10.2214/AJR.05.1652

26. Park HS, Chamarthy MR, Lamus D, Saboo SS, Sutphin PD, Kalva SP. Pulmonary artery aneurysms: diagnosis & endovascular therapy. Cardiovasc Diagn Ther. 2018;8(3):350-61.doi: 10.21037/cdt.2018.04.01

27. Samano M, Ladeira R, Meireles L, Pego-Fernandes P. Aneurisma de artéria pulmonar como manifestação da doença de Behçet (Pulmonary artery aneurysm as a manifestation of Behcet disease: case report and review). J Bras Pneumol. 2002;28:150-4.doi: 10.1590/S0102-35862002000300007

28. Kim HY, Song K-S, Goo JM, Lee JS, Lee KS, Lim T-H. Thoracic sequelae and complications of Tuberculosis. Radiographics. 2001;21(4):839-58.doi: 10.1148/radiographics.21.4.g01jl06839

29. Leung AN. Pulmonary Tuberculosis: The essentials. Radiology. 1999;210(2):307-22.doi: 10.1148/radiology.210.2.r99ja34307

30. Sahoo S, Panigrahi MK, Naik S, Mohapatra PR. Rasmussen’s aneurysm masquerading as mass lesion. BMJ Case Rep. 2020;13(2):e232669.doi: 10.1136/bcr-2019-232669

31. Ivkovic S, Milosavljevic T, Ivkovic A. MDCT with angiography in Rasmussen aneurysms. Eur Respir J. 2014;44(Suppl 58):P2631

32. Campos LG, da Silva EC, Rangel AFR, de Souza MD, Musso C. Pulmonary artery aneurysm rupture. Autops Case Rep. 2019;10(1):e2019131-e.doi: 10.4322/acr.2019.131

33. Gupta M, Agrawal A, Iakovou A, Cohen S, Shah R, Talwar A. Pulmonary artery aneurysm: a review. Pulm Circ. 2020;10(1):2045894020908780.doi: 10.1177/2045894020908780

34. Sanyika C, Corr P, Royston D, Blyth DF. Pulmonary angiography and embolization for severe hemoptysis due to cavitary pulmonary tuberculosis. Cardiovasc Intervent Radiol. 1999;22(6):457-60.doi: 10.1007/s002709900432

35. Zhang Y, Chen C, Jiang G-n. Surgery of massive hemoptysis in pulmonary tuberculosis: Immediate and long-term outcomes. J Thorac Cardiovasc Surg. 2014;148(2):651-6.doi: 10.1016/j.jtcvs.2014.01.008

36. Fernando HC, Stein M, Benfield JR, Link DP. Role of bronchial artery embolization in the management of hemoptysis. Arch Surg. 1998;133(8):862-6.doi: 10.1001/archsurg.133.8.862

37. Balcı E, Demir A, Özgök A, Karadeniz Ü. Anaesthesia management in idiopathic pulmonary artery aneurysm surgery. Turk J Anaesthesiol Reanim. 2019;47(6):503-6.doi: 10.5152/TJAR.2019.21447

38. Heijkoop B, Gillespie H, Kiroff G. Emergency management of massive haemoptysis. BMJ Case Rep. 2019;12(1).doi: 10.1136/bcr-2018-225620

39. Radchenko C, Alraiyes AH, Shojaee S. A systematic approach to the management of massive hemoptysis. J Thorac Dis. 2017:S1069-S86.doi: 10.21037/jtd.2017.06.41

40. Panda A, Bhalla AS, Goyal A. Bronchial artery embolization in hemoptysis: a systematic review. Diagn Interv Radiol. 2017;23(4):307-17.doi: 10.5152/dir.2017.16454

41. Ugajin A, Fujii H, Nakamura H, Fujita A, Sasaki T, Mato N, et al. Transcatheter proximal coil blocking with n-Butyl-2-Cyanoacrylate injection via the pulmonary artery alone for Rasmussen's aneurysm. Case Rep Radiol. 2019;2019:1725238.doi: 10.1155/2019/1725238

42. Lee BR, Yu JY, Ban HJ, Oh IJ, Kim KS, Kwon YS, et al. Analysis of patients with hemoptysis in a tertiary referral hospital. Tuberc Respir Dis. 2012;73(2):107-14.doi: 10.4046/trd.2012.73.2.107

43. Ong T-H, Eng P. Massive hemoptysis requiring intensive care. Intensive Care Med. 2003;29(2):317-20.doi: 10.1007/s00134-002-1553-6

44. Reechaipichitkul W, Latong S. Etiology and treatment outcomes of massive hemoptysis. Southeast Asian J Trop Med Public Health. 2005;36(2):474-80.PMID: 15916059

45. Harmon TS, Kaleka G, Maciolek LM, Kathuria MK, Gill GS, Hussain A, et al. Becoming the standard: Expanding the conventional use of interventional embolization for ruptured pulmonary artery aneurysms. Cureus. 2018;10(11):e3576-e.doi: 10.7759/cureus.3576

46. Matsumura Y, Shiono S, Saito K, Sato T. Pulmonary artery pseudoaneurysm after lung resection successfully treated by coil embolization. Interact Cardiovasc Thorac Surg. 2010;11(3):364-5.doi: 10.1510/icvts.2010.236661

47. Jagia P, Sharma S, Juneja R, Guleria R. Transcatheter treatment of pulmonary artery pseudoaneurysm using a PDA closure device. Diagn Interv Radiol. 2011;17(1):92-4.doi: 10.4261/1305-3825.Dir.2657-09.1

48. Kathuria H, Hollingsworth HM, Vilvendhan R, Reardon C. Management of life-threatening hemoptysis. J Intensive Care. 2020;8(1):23.doi: 10.1186/s40560-020-00441-8

49. Chang B, Kaye AD, Diaz JH, Westlake B, Dutton RP, Urman RD. Interventional procedures outside of the operating room: Results from the National

Anesthesia Clinical Outcomes Registry. J Patient Saf. 2018;14(1):9-16.doi: 10.1097/pts.0000000000000156

50. Amin A, Lane JS. The future of anesthesia for interventional radiology. Curr Opin Anaesthesiol. 2018;31(4):469-72.doi: 10.1097/aco.0000000000000609

51. Vari A, Gangi A. Anesthesia practices for interventional radiology in Europe. Cardiovasc Intervent Radiol. 2017;40(6):803-13.doi: 10.1007/s00270-017-1576-6

52. Azizad O, Joshi G. Overview of anesthesia for interventional radiology Waltham, (MA): UpToDate.com; 2019 [updated 19 August 2019; cited 2021 17 February]. Available from: https://www.uptodate.com/contents/overview-of-anesthesia-for-interventional-radiology-procedures?search=anaesthesia%20interventional%20radiology&source=search_result&selectedTitle=1~150&usage_type=default&display_rank=1.

53. Landrigan-Ossar M. Common procedures and strategies for anaesthesia in interventional radiology. Curr Opin Anaesthesiol. 2015;28(4):458-63.doi: 10.1097/aco.0000000000000208

54. Selzer AR, Murrell M, Shostak E. New trends in interventional pulmonology. Curr Opin Anaesthesiol. 2017;30(1):17-22.doi: 10.1097/aco.0000000000000414

55. Segura-Salguero JC, Díaz-Bohada L, Lutz-Peña JR, Posada AM, Ronderos V. Perioperative management of massive hemoptysis during flexible bronchoscopy: Case report. Rev Colomb de Anestesiol. 2017;45(3):256-61.doi: 10.1016/j.rcae.2017.05.001

56. Derbent A, Oran I, Parildar M, Yurtseven T, Uyar M, Memiş A. Adverse effects of anesthesia in interventional radiology. Diagn Interv Radiol. 2005;11(2):109-12.PMID: 15957099

57. Haj-Yahia S, Sbaih M, Bali K, Darwazah A, Othman W, Zaghari M, et al. Case report and management approach in idiopathic pulmonary arteries aneurysm. J Cardiothorac Surg. 2018;13(1):110-.doi: 10.1186/s13019-018-0791-9

58. Veldtman GR, Dearani JA, Warnes CA. Low pressure giant pulmonary artery aneurysms in the adult: natural history and management strategies. Heart. 2003;89(9):1067-70.doi: 10.1136/heart.89.9.1067

59. João BB, Bueno RM, Marques GDA, Soares FB. Anesthesia for pulmonary trunk aneurysmorrhaphy. Braz J Anesthesiol. 2017;67(1):95-9.doi: 10.1016/j.bjane.2013.03.027

60. Ekim H, Gelen T, Karpuzoğlu G. Multiple aneurysms of the cephalic vein. A case report. Angiology. 1995;46(3):265-7.doi: 10.1177/000331979504600311

61. Rivera P, Dattilo J. Pseudoaneurysm Treasure Island, Florida: StatPearls Publishing; 2020 [updated 13 September 2020; cited 2021 1 November]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK542244/.

62. Senbaklavaci O, Kaneko Y, Bartunek A, Brunner C, Kurkciyan E, Wunderbaldinger P, et al. Rupture and dissection in pulmonary artery aneurysms: incidence, cause, and treatment--review and case report. J Thorac Cardiovasc Surg. 2001;121(5):1006-8.doi: 10.1067/mtc.2001.112634

63. Chandra AS, Rajalingam K, V. KBR, Prasad PK. A study of lung resection for haemoptysis with or without pre-operative bronchial artery embolisation. Int Surg J. 2016;3(3):5.doi: 10.18203/2349-2902.isj20162709

64. Noë GD, Jaffé SM, Molan MP. CT and CT angiography in massive haemoptysis with emphasis on pre-embolization assessment. Clin Radiol. 2011;66(9):869-75.doi: 10.1016/j.crad.2011.03.001

65. Inside Radiology. Interventional Radiology Australia: Inside Radiology.com; 2018 [updated 4 October 2018. Available from: https://www.insideradiology.com.au/interventional-radiology/.

66. Buitenwerf E, Boekel MF, van der Velde MI, Voogd MF, Kerstens MN, Wietasch GJKG, et al. The haemodynamic instability score: Development and internal validation of a new rating method of intra-operative haemodynamic instability. Eur J Anaesthesiol. 2019;36(4):290-6.10.1097/eja.0000000000000941

67. World Medical Association. Declaration of Helsinki: Ethical principles for medical research involving human subjects: World Medical Association; 2013 [Available from: https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/.

68. Department of Health. South African Good Clinical Practice: Clinical Trial Guidelines. Pretoria, South Africa2019.

69. Hess DR. Retrospective studies and chart reviews. Respir Care. 2004;49(10):1171-4

70. Street C, Ward K. Encyclopedia of case study research. 2010.doi: 10.4135/9781412957397

71. Ranganathan P, Aggarwal R. Study designs: Part 1 - An overview and classification. Perspect Clin Res. 2018;9(4):184-6.doi: 10.4103/picr.PICR_124_18

72. Nickson C. Restrospective studies and chart reviews: Life in the Fastlane; 2020 [updated 3 November 2020. Available from: https://litfl.com/retrospective-studies-and-chart-reviews/.

73. Brink H, Van der Walt C, Van Rensburg G. Fundamentals of Research Methodology for Healthcare Professionals. 3rd ed. Cape Town, South Africa: Juta; 2012.

4.12 Appendices

4.12.1 Appendix 1: Letters of approval to conduct study

Hannah Stuart-Clark
Anaesthesiology registrar
University of the Witwatersrand
Student number: 2062634

5 June 2021

Prof. Palesa Motshabi
Principal Specialist
Head of Department of Anaesthesiology
University of the Witwatersrand

Dear Prof. Motshabi,

RE: Permission to conduct a study

I would like to request permission to conduct the MMed study titled: Retrospective case series of the anaesthetic management and outcomes of patients with Rasmussen's aneurysms at an academic hospital.

The aim of this study is to describe the periprocedural anaesthetic management and outcomes of patients presenting with Rasmussen's aneurysms to interventional radiology for bronchial artery embolization at Chris Hani Baragwanath Academic Hospital.

Tuberculosis has a high burden of disease in South Africa and approximately 5% of patients who present with haemoptysis are found to have a Rasmussen's aneurysm. Although Rasmussen's aneurysms are rare, if they present with massive

haemoptysis, they have a high mortality rate. In our resource limited setting, the availability of diagnostic tools and specialist management options such as bronchial artery embolization may not be readily available for patients who present with massive haemoptysis.

The use of minimally invasive techniques for the management of these patients is gaining popularity, however there is a paucity of data with regards to anaesthetic management in the interventional radiology suite. There are currently no clear or definitive therapeutic guidelines for the anaesthetic management of patients with Rasmussen's aneurysms. The interventional radiology suite at Chris Hani Baragwanath Academic Hospital provides us with the unique opportunity to review the management of patients presenting with Rasmussen's aneurysms. Most of the literature on the topic focuses on single case reports due to the rarity of the pathology. The results of this study will provide insight into anaesthetic techniques used for patients with Rasmussen's aneurysms as well as provide demographic information and outcomes of the interventions used.

Yours sincerely,

Hannah Stuart-Clark

Approval granted:

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL
DIRECTORATE - ANAESTHESIA
Enquiries: Dr P. Mogane
Tel. number: (011) 933-9334
Email: Palesa.Mogane@wits.ac.za

Department of Anaesthesiology
Chris Hani Baragwanath Academic Hospital
PO Bertsham
2013
14th June 2021

To whom it may concern

RE: PERMISSION TO CONDUCT RESEARCH

This serves to confirm that I grant permission for Dr Hannah-Stuart Clark to conduct research involving the Department of Anaesthesia at the Chris Hani Baragwanath Academic Hospital. The research topic is titled:
The evaluation of anaesthetic management and outcomes of patients presenting with Rasmussen's aneurysms at Chris Hani Baragwanath Academic hospital.

I'd like to wish her luck in this endeavor and I am happy to support her wherever possible.

Kind regards.

Dr Palesa Mogane
Chief specialist and Head of Department
Department of Anaesthesiology
Chris Hani Baragwanath Academic Hospital
University of Witwatersrand
Email: Palesa.Mogane@wits.ac.za

CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL – UNIVERSITY OF THE WITWATERSRAND
DEPARTMENT OF RADIOLOGY

RE: RESEARCH PROJECT IN CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL

Dear Sir/Madam

Project title- Retrospective case series anaesthetic management and outcomes of patients with Rasmussen's aneurysms at an academic hospital
at Chris Hani Baragwanath Academic Hospital:
Period of study: January 2017 to June 2021

Study type: Retrospective case series

We hereby grant permission to Dr Hannah Stuart-Clark application, a Masters student from the University of the Witwatersrand, to conduct research in our hospital for purposes of a Masters of Medicine qualification (Anaesthesia). This will include permission to access the radiologic images and reports of all patients with Rasmussen's aneurysms during the study period using the radiology database PACS system.

All data will be anonymous by assigning a pseudo number to each patient.

Permission is granted to Dr Hannah Stuart-Clark, subject to him/her obtaining ethical clearance to conduct research from the Ethics Committee of the University of the Witwatersrand, Johannesburg and by abiding to its terms.

I have been informed about Dr Hannah Stuart-Clark's research.

Yours sincerely,

Prof. Victor Mngomezulu
Head of Clinical Department: Diagnostic Radiology
Chris Hani Baragwanath Academic Hospital

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

MEDICAL ADVISORY COMMITTEE

CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL

PERMISSION TO CONDUCT RESEARCH

Date: 25 August 2021

TITLE OF PROJECT:

Retrospective case series of the anaesthetic management and outcomes of patient with Rasmussen's aneurysm at an academic hospital.

UNIVERSITY: Witwatersrand

Principal Investigator: Dr HE Stuart-Clark

Department: Anaesthesia

Supervisor/s : Dr P Mogane / Dr J Padi

Permission Head Department (where research conducted): Yes

NHRD No. 202106 037

The Medical Advisory Committee recommends that the said research be conducted at Chris Hani Baragwanath Academic Hospital. The CEO / management of Chris Hani Baragwanath Academic Hospital is accordingly informed and the study is subject to:-

- Permission having been granted by the Committee for Research on Human Subjects of the University of the Witwatersrand.
- The Hospital will not incur extra costs as a result of the research being conducted on its patients within the hospital
- The MAC will be informed of any serious adverse events as soon as they occur
- Permission is granted for the duration of the Ethics Committee Approval.

Recommended
(On behalf of the MAC)
2021/08/25

Approved/Not Approved
Hospital Management Date:
Date: 26/08/2021

Appendix 2: Data collection sheets

Demographics:

Study number	
Age	
Gender	
Race	
Presenting Complaint	
Cause/Diagnosis	
Comorbidities	
Method of diagnosis	

Anaesthetic Management

ASA status	1	2	3	4	E
Anaesthetic performed by	Anaesthesiology staff member		Interventional radiology staff member		
Skill level of anaesthetist	Consultant	Registrar	Medical Officer	Other	

Anaesthesia consultant supervision	Yes		No	
Time of day procedure performed	Weekday 08:00 – 16:00	Weekday 16:00 – 08:00	Weekend 08:00 – 16:00	Weekend 16:00 – 08:00
Vitals pre-procedure	HR	BP	MAP	Sats
Pre-procedure vasopressor or inotropic support	Yes	No	Drug and dose	
Haemodynamic status (according to HI score)	Stable		Unstable	
Anaesthetic technique	GA	LA	Sedation	
Airway management	Spontaneous	Control		
Airway management technique	FMO_2	SLT	DLT	LMA
One lung ventilation/isolation	Yes	No		
Isolation technique	DLT	Bronchial blocker	SLT advanced into non affected side main bronchus	Other
Invasive monitoring	Arterial Line	Central Venous Cather	Other	
	Site	Site		
Complications				

(Need for inotropic support, need for transfusion, difficult lung isolation, etc)								
Anaesthetic chart	Completed adequately				Chart available			
Initial ABG	pH	pCO2	pO2	Hb/Hct	HCO3	Lac	BE	Sats
Serial ABGs	pH	pCO2	pO2	Hb/Hct	HCO3	Lac	BE	Sats
	pH	pCO2	pO2	Hb/Hct	HCO3	Lac	BE	Sats
	pH	pCO2	pO2	Hb/Hct	HCO3	Lac	BE	Sats
	pH	pCO2	pO2	Hb/Hct	HCO3	Lac	BE	Sats
Post-operative destination	Ward		High Care		ICU		Other	

Intervention used and outcomes

Interventional technique used	Coiling	Glue embolization or other	Stent	Other
Complications				

(Difficult embolization, failure of embolization, etc)	
Duration of procedure	
Volume of contrast used	
Dose of radiation	
Morbidity (rebleed, need for re-embolization)	**Mortality (7 day)**

Chapter 5 Annexures

5.1 Ethics approval

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

R49 Dr HE Stuart-Clark

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M210717

NAME: (Principal Investigator)	Dr HE Stuart-Clark
DEPARTMENT:	School of Clinical Medicine Department of Anaesthesiology Medical School University
PROJECT TITLE:	*Retrospective case series of the anaesthetic management and outcomes of patients with Rasmussen's aneurysms at an academic hospital*
DATE CONSIDERED:	2021/07/30
DECISION:	Approved unconditionally
CONDITIONS:	
NOTE:	If contact information regarding student study participants is required, please contact the Registrar's office - <Nicoleen.Potgieter@wits.ac.za>
SUPERVISOR:	Drs P Moganane and J Padi
APPROVED BY:	Dr CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	2021/08/20

This Clearance Certificate is valid for 5 years from the date of approval. An extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office secretariat on the 3rd floor, Phillip Tobias Building, Parktown, University of the Witwatersrand, Johannesburg.

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 submit details to the Committee. **I agree to submit a yearly progress report.** When a funder requires annual re-certification, the application date will be one year after the date when the study was initially reviewed. In this case, the study was initially reviewed in July and therefore reports and re-certification will be due in the month of July each year. Unreported changes to the study may invalidate the clearance given by the HREC (Medical).

Signature of Principal Investigator

21/09/2021
Date

5.2 Graduate studies approval

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

Private Bag 3 Wits, 2050
Fax: 027117172119
Tel: 02711 7172076

Reference: Mrs Sandra Benn
E-mail: sandra.benn@wits.ac.za

31 August 2021
Person No: 2062634
PAG

Dr HE Stuart-Clark
Suite 80
Private Bag X 4006
Ferndale
2194
South Africa

Dear Dr Hannah Stuart-Clark

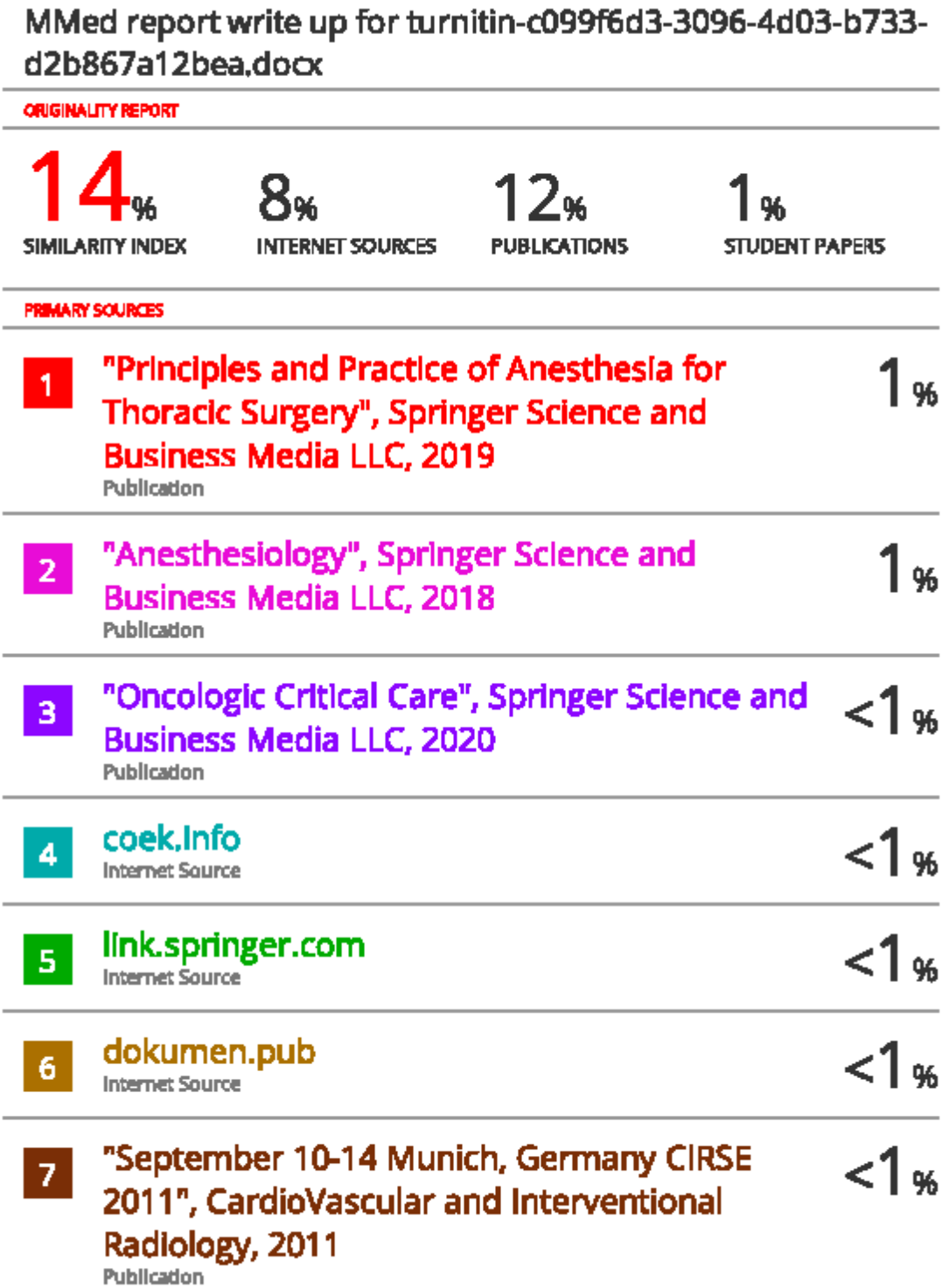
Master of Medicine in Anaesthesia: Approval of Title

We have pleasure in advising that your proposal entitled *Retrospective case series of the anaesthetic management and outcomes of patients with Rasmussen¿s aneurysms at an academic hospital* 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

5.3 Turnitin report



MMed report write up for turnitin-c099f6d3-3096-4d03-b733-d2b867a12bea.docx

ORIGINALITY REPORT

14%	8%	12%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	"Principles and Practice of Anesthesia for Thoracic Surgery", Springer Science and Business Media LLC, 2019 Publication	1%
2	"Anesthesiology", Springer Science and Business Media LLC, 2018 Publication	1%
3	"Oncologic Critical Care", Springer Science and Business Media LLC, 2020 Publication	<1%
4	coek.info Internet Source	<1%
5	link.springer.com Internet Source	<1%
6	dokumen.pub Internet Source	<1%
7	"September 10-14 Munich, Germany CIRSE 2011", CardioVascular and Interventional Radiology, 2011 Publication	<1%