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

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Abstract

Background

Tuberculosis (TB) has a high burden of disease in South Africa, and a Rasmussen's aneurysm is a late complication of TB. Although rare, the risk for life-threatening complications is high (>50%). 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.

This study aimed to describe the periprocedural anaesthetic management and outcomes of patients presenting with Rasmussen's aneurysms treated with PAE in the interventional radiology suite at an academic hospital.

Methods

This was a retrospective case series, and arterial embolization (AE) records were collected over the years. All patients identified with Rasmussen's aneurysms were included in the study.

Results

The prevalence of Rasmussen's aneurysms was 9%. Of the sixteen patients included in the study, thirteen were male, and three were female. 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 was 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 covered by 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 sent to a high-dependency unit post-procedure.

Conclusion

This study provides several novel insights into the prevalence and anaesthetic management of Rasmussen's aneurysms in patients presenting with haemoptysis for PAE.

Recommendation

The study recommends implementing multidisciplinary, protocol-driven peri-procedural care with thorough preoperative assessment, appropriate monitoring, skilled anaesthesia support, and postoperative high-care management to optimise outcomes in patients with Rasmussen's aneurysms.

Key words: *Rasmussen's aneurysms, Haemoptysis, Tuberculosis, Pulmonary Artery Embolization*
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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 are 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 that 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 RAs every year. Despite this, there is a paucity of information regarding the anaesthetic management of these patients within this setting. This study aimed 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).

Methods

Study Design

This study used a retrospective case series design. The final sample size was determined by the number of cases done in the study period.

Study setting

Pulmonary artery embolization was introduced to CHBAH in January 2017, and all the AE records from the IR suite collected over the years, starting in January 2017 until the end of June 2021, were examined for relevance. CHBAH is a tertiary, 3000-bed, public hospital in Johannesburg, Gauteng, South Africa. It is the largest hospital in Africa, providing all services except Bariatrics, Transplant, and Cardiothoracic surgery. The hospital is affiliated with the University of the Witwatersrand. The hospital provides highly specialised medical and surgical services, with more than 2000 patients seen by the Internal Medicine Department, reflecting the substantial healthcare demands of its large catchment population. The patient population served is characterised by a high burden of communicable disease, particularly tuberculosis.

Study population

All patients identified in the records with RA were then selected for inclusion in the study. Incomplete files (> 50% data) were excluded. 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.

Statistical analysis

Data was captured in a Microsoft Excel spreadsheet and analysed. Demographic data such as age, gender, race, and comorbidities are summarized in Table 1. Anaesthetic management and interventional radiology data are described in Table 2. Where possible, categorical variables were expressed as percentages, and numerical variables were expressed as median values with an interquartile range.

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Bias minimisation

Bias in this retrospective study can be minimised by applying strict inclusion and exclusion criteria, such as excluding incomplete records to improve data reliability, and using multiple data sources to enhance data completeness and accuracy. Standardised data collection methods and predefined variables also help reduce measurement bias. Furthermore, transparent reporting of missing data, limitations in record availability, and potential selection bias ensure a more balanced interpretation of findings, thereby strengthening the validity of the study conclusions.

Ethical considerations

The protocol was approved by the University of Witwatersrand's Human Research and Ethics Committee (Medical) (M210717) on 28/09/2021. Permission from all other relevant authorities was also obtained.

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 PAEs 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 1.

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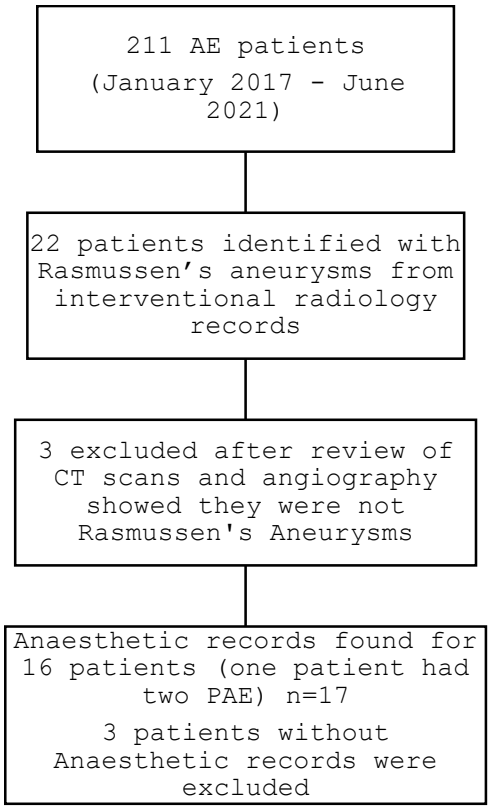

Figure 1: Schematic explaining the inclusion and exclusion criteria applied in this study.

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 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 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 1.

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Table 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%)	

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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 Tables 2 and 3.

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 before their PAE after having presented with haemoptysis at admission.

Airway management technique is summarized in Table 2. Pre-procedural and intra-procedural transfusions are summarized in Table 2. Preoperative blood results and initial vitals are represented as median values with interquartile ranges in Table 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 are summarised in Table 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 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 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).

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Table 2: Summary of anaesthetic management

	Count (Percentage) = n (%)	Median [IQR]
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%)	
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%)	

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Aneurysm Rupture	1 (6%)
Arrhythmia	2 (12%)
Bronchial Lavage	3 (18%)
Delayed Emergence	1 (6%)
Difficult Ventilation	3 (18%)
Endotracheal Tube blocked with a 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%)

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).

Table 3: Summary of interventional radiology management

Intervention type	Count (Percentage) = n (%)	Median [IQR]
Elective	9 (53%)	
Emergency	8 (47%)	
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 (hours: minutes)		04:05 [03:05 – 05:30]
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]

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 whom 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.

Discussion

Rasmussen's aneurysms are rare, with a prevalence ranging from between 0.25% to 4-5% in patients with TB (7, 8). The study 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

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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 a 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 is 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 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 advocates 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 an 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 historical 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 in whom the aneurysm ruptured during the PAE. Three patients had reported difficulty with ventilation on their anaesthetic records during the procedure, two of whom were reported to have a clot blocking their endotracheal tube on extubation. Two of the patients developed an arrhythmia during guidewire placement before 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 recommends 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, the study was unable to adequately assess outcomes, which was a significant limitation of the

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study. Of the six patients whose hospital ward files were found, none were noted to have recurrent haemoptysis post-PAE before 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.

Generalisability

The findings of this study can be applied to other South African hospitals, provided there is the availability of adequately skilled clinicians and equipment.

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.

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. The study was 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 prevent the 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.

Recommendations for the peri-procedural anaesthetic management

Given the findings of the study, 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 are 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 $\leq$ 1.5, an aPTT $\leq$1.5x control, and a platelet count $\geq$ 50 x 109/L (43, 45), a normal creatinine and Glomerular Filtration Rate, and a Haemoglobin $\geq$ 8g/dL. Our cohort of patients had a mean haemoglobin level of 10.5 g/dL (9.7 – 11.9), a mean creatinine of 67.5 umol/L (50.8 – 76.5), a mean INR of 1.22 (1.12 – 1.33), and a mean platelet count of 393 x109/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

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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 a lack of visualization and the inability 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 a 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 and 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; 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; 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, a 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).

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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.

Postoperative 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 perioperative respiratory complications. (51). The guidelines for tracheal extubation published by the Difficult Airway Society should be followed to guide extubation in this setting. (57).

Conflict of interest

The authors have no conflicts of interest to declare.

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List of 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
O2 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

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Data availability

Data is available for review on request from the authors.

Author contributions

Hannah Stuart-Clark conceptualised the study, led the research design, collected data, contributed to data analysis, writing, drafting, and finalising the manuscript. https://orcid.org/0000-0002-0317-1003
Josias Padi supported data collection, assisted with data interpretation, and contributed to writing and revising the manuscript.
Palesa Mogane contributed to the literature review, data interpretation and verification, and critical revision of the final manuscript. https://orcid.org/0000-0002-5523-4539
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Main author biography

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