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A Retrospective Review of the Intracranial Aneurysms treated with Endovascular Coiling at Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) for the period of January 2012 to December 2013

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A research report submitted to the University of Witwatersrand, Medical School, in fulfilment of requirements for the MMED Degree

December 2015

Declaration

I hereby declare that this research report is my own, unaided work. The Wisconsin referencing format is used as a standard set by the university. The research report is submitted for the Degree in Master of Medicine at the University of the Witwatersrand, Johannesburg, Medical School. It has not been submitted prior to this for any other degree or examination at any other university.

Dr. A. Kajee

Date

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Abbreviation of key words used

ACA Anterior Cerebral Artery

ACoA Anterior Communicating Artery

BA Basilar Artery

CBF Cerebral Blood Flow

CBV Cerebral Blood Volume

CE-MRA Contrast-Enhanced Magnetic Resonance Angiography

CI Confidence Interval

CSF Cerebrospinal Fluid

CT Computed Tomography

CTA Computed Tomography Angiography

CTP Computed Tomography Perfusion

DSA Digital Subtraction Angiography

GCS Glasgow Coma Scale

GDC Guglielmi Detachable Coils

GOS Glasgow Outcome Scale

GRE Gradient Echo Sequence

H&H Hunt and Hess Scale

ICA Internal Carotid Artery

ICH Intracerebral Hematoma

ICP Intracranial Pressure

ISUIA International Study of Unruptured Aneurysms

ISAT International Subarachnoid Aneurysm Trail

IVH Intraventricular Haemorrhage

MCA Middle Cerebral Artery

MRA Magnetic Resonance Angiography

MRI Magnetic Resonance Imaging

PCA Posterior Cerebral Artery

PcommA Posterior Communicating Artery

RVD Retroviral Disease

SAH Subarachnoid Haemorrhage

Triple-H Therapy combination of induced hypertension, hypervolemia and hemodilution

VBA Vertebro-Basilar Artery

WFNS World Federation of Neurosurgical Surgery

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Chapter 1: Introduction

1.1) Aim

Subarachnoid haemorrhage (SAH) remains a serious condition with high mortality and disability. The most common cause in 85% of cases of a non- traumatic subarachnoid haemorrhage is the rupture of an intracranial aneurysm (1). In past decades there have been improvements in techniques to secure aneurysms both surgically and by endovascular technique. The aim of this research report is to investigate the endovascularly coiled cases at the Charlotte Maxeke Johannesburg Academic Hospital done over a period of two years.

Within the South African context endovascular services are only just beginning. As we initiated endovascular services at CMJAH it called for an evaluation of the cases treated. Coil embolization has become an established modality for the treatment of ruptured and unruptured intracranial aneurysms (2). The Neurosurgery Department at CMJAH has recognised this as an entity to begin, sustain and continue for the optimal management of patients who present with subarachnoid haemorrhage on an aneurysmal basis. This research report will highlight the importance of interdisciplinary co-operation in the diagnosis, treatment and overall management of intracranial aneurysms.

1.2) Rationale

Endovascular treatment of intracranial aneurysms has evolved rapidly worldwide within the last decade and has gained more popularity than surgical clipping (3). Although lagging behind international trends, the endovascular coiling of intracranial aneurysms began at CMJAH in January 2012 as collaboration between the neurosurgical and radiological departments. It stands to reason that a critical analysis of the work done over a two year period is to be evaluated. The significance of this kind of evaluation cannot be underestimated as it informs clinical practice for the development of the Neurosurgery and Radiology Units at CMJAH. The assessment of such unit outcomes is more worthy when introducing new techniques for patient care.

1.3) Research Questions

- To establish the proportion of cases that were successfully coiled and those that were not successfully coiled.
- To determine the percentage of the complications.
- To describe the characteristics (demographics, clinical criteria, aneurysm location and size etc.) of cases that were successfully coiled.
- To determine the prevalence of death, disability or return to normal state after coiling.

Chapter 2- Literature Review

2.1) Introduction

The literature review sets out to explore the management of intracranial aneurysms by providing a background on the incidence, histopathology, clinical presentation, radiological investigation and endovascular management of subarachnoid haemorrhage that is caused by intracranial aneurysms. In order to provide a context in which to do this, the following will be discussed under these sections:

2.2) Intracranial aneurysms

2.3) Subarachnoid haemorrhage

2.4) Management of aneurysms by endovascular coiling.

2.5) Complications of endovascular coiling

2.6) Outcomes of endovascular coiling

2.7) Further applications for endovascular coiling

2.8) Conclusion

2.2) Intracranial Aneurysms

The prevalence of intracranial aneurysms in most published results of large studies ranges from 0.4%-6% of the general population (4). The interest in management is related to the high morbidity and mortality associated with treatment. As a result management options such as neurosurgical clipping and neuro-interventional coiling have been the subject of much investigation. Intracranial aneurysms are not congenital as once thought but develop in the course of life (5). The estimated frequency of aneurysms for an average adult without specific risk factors is 2-3% in their lifetime (95% CI 1.7-3.1) this proportion increases with age (5).

In up to 30% of patients more than one intracranial aneurysm is present, a state which is defined as 'multiple aneurysms'. Within the subgroup of patients with multiple aneurysms about one-third has mirror aneurysms (two different aneurysms located bilaterally on corresponding arteries) (6). The prevalence of harbouring an intracranial aneurysm varies between autopsy studies and angiography studies, with estimates ranging from 0.2% to 9.9% with a mean of approximately 5% (6).

Modifiable risk factors for subarachnoid haemorrhage are hypertension, smoking, and excess alcohol intake all of which more or less double the risk (5). Modifiable risk factors account for two of every haemorrhages and genetic factors, for one in every ten (5). The estimated annual rate of aneurysmal subarachnoid in most western populations is 6-8 per 100000 population (7).

Intracranial aneurysms result from degradation of the arterial wall which is caused by both congenital and acquired (e.g. hypertension, smoking etc.) aetiologies. (8). Enlargement and rupture of the aneurysm results from the interplay between continuing degradation of the arterial wall and haemodynamics (8). Saccular aneurysms arise at sites of arterial branching, usually at the base of the brain either on the Circle of Willis itself or at a nearby branching point (5). The size, site, number and symptomatology of the aneurysm all contribute to rupture risk (9).

In addition to saccular intracerebral aneurysms other shapes of aneurysms such as fusiform or dissecting, also commonly form in and around the circle of Willis, as such, all shapes of aneurysms can form within the anterior and posterior communicating arteries. The risk of rupture is proportional to the diameter of the aneurysm, although the majority of ruptures occur in small-diameter aneurysms as they are much greater in number than large-diameter ones. It should be emphasized that not all intracranial aneurysms burst or cause any symptoms. As many as 2% of the general population have an intracranial aneurysm but are unaware of it (3).

The natural history of a ruptured intracranial aneurysm has a 3-18% mortality rate even before hospitalization (9). Once an intracranial aneurysm has ruptured the complications that can result other than subarachnoid haemorrhage include: intracerebral haemorrhage, vasospasm, hydrocephalus and cerebral infarction (10). The risk of re-rupture during the first

few days to weeks is high enough to warrant early intervention (11).

When an aneurysm bursts, the flow of blood into the subarachnoid space causes an immediate rise in the intracranial pressure that is large enough to obstruct cerebral perfusion. This is responsible for the loss of consciousness experienced by many who suffer a subarachnoid haemorrhage. Resultant ischemia due to a decline in perfusion does not always result in cerebral infarction; instead it depends on many factors including the extent of the fall and duration of perfusion, and the competence of homeostatic measures. The brain normally receives about 50ml/100g/min of blood (9). It is only when perfusion falls to around 10ml/100g/min of blood that neurons sustain permanent damage. Homeostatic measures employed by the body to correct the situation includes plugging the haemorrhage and draining leaked blood, allowing perfusion to return to normal levels very shortly.

Cerebral oedema occurring due to fluid accumulation within damaged cells (cytotoxic oedema) or cerebrospinal fluid (CSF) leakage into the interstitial space (vasogenic oedema) exacerbates the raised ICP and negatively impacts efforts to correct it, via triple – H therapy usually employed in the initial management of the SAH (1).

2.3) Subarachnoid Haemorrhage

SAH's can be categorized as either spontaneous or traumatic. The aetiology of spontaneous SAH can be anatomic (aneurysmal, vascular anomaly e.g. arterio-venous malformation), secondary to a tumour, bleeding dyscrasias, hypertension and infection. Traumatic causes account for fewer than 10% of cases compared to 85% of SAH cases linked specifically to aneurysms. Other rare causes, such as borreliosis, cerebral arteriovenous malformations and cervical meningiomas, account for the remaining 5%. Modifiable risk factors of SAH include smoking, excessive alcohol consumption, exercise and hypertension. The importance of these modifiable risk factors is emphasized by studies suggesting they cause 66% of haemorrhages, compared to only 10% that are attributed to genetic susceptibility (3).

The peak age for aneurysmal subarachnoid haemorrhage is 55-60 years (7). Thirty percent of aneurysmal subarachnoid haemorrhages occur during sleep and 30-60% of patients report a sentinel bleed or 'warning headache' (7). Subarachnoid haemorrhage presents with headache in up to 97% of cases, and 30% can be lateralised to the side of the aneurysm (7). Typically described as a thunder clap headache accompanied by vomiting, neck pain, and photophobia (10). On admission clinical signs include meningism, hypertension, focal neurological deficit and two thirds of patients have a depressed level of consciousness (10). The change in level of consciousness can range from lethargy, confusion, agitation or obtundation (6). To

score the levels of consciousness using the Glasgow coma scale further assists with grading of the SAH according to the WFNS grading (Appendix A). Types of occular haemorrhages that occur with a SAH include sub-hyaloid, intra-retinal and haemorrhages within the vitreous humor (Terson syndrome) (10). The risk of rebleeding after a subarachnoid haemorrhage is greatest on the first day, with a rate ranging from 4% up to 14% (12). By day 14, the cumulative re-bleed incidence is approximately 19%.

Work up for a suspected SAH includes non-contrast CT scan (12). If the CT is deemed to be negative a lumbar puncture in suspicious cases can be considered (10). To identify the source of the SAH; CT Angiography, MR Angiography or Digital Subtraction Angiography can be used taking into account the patients age and renal function (10). A good quality CT will detect a SAH in > 95% of cases and the use of Fisher grading will determine severity of the SAH (12). Haemorrhage from an intracranial aneurysm might not be confined to a subarachnoid cisterns but can rupture into brain tissue, the ventricular system or sometimes the subdural space. The location of the intracerebral haematoma usually indicates the site of the ruptured aneurysm more reliably than cisternal blood (5).

Angiographic studies in general serve not only to identify one or more aneurysms as potential causes of SAH but also to study the angiographic configuration of the aneurysm in relation to the adjoining arteries which allows optimum selection of treatment that is coiling or clipping. While CT angiography is a

continuously improving technique, the sensitivity for detecting ruptured aneurysms with CT angiography as a gold standard is currently about 95% (10). Digital subtraction angiography or catheter angiography is not an innocuous procedure and in patients with SAH the rate of ischaemic complications (transient or permanent) is 1-8 % and aneurysm re-rupture during the procedure is 1-2 % overall (5).

2.4) Management of Aneurysms by Endovascular Coiling

The treatment goal of intracranial aneurysms is to isolate them from the parent circulation (7). In ruptured aneurysms, this must be done early so that the maximum treatment of cerebral vasospasm can be given if necessary (1). Symptomatic cerebral vasospasm can be managed with Triple H-therapy (involving hypertension, hypervolaemia, and haemodilution) and by endovascular administration of intra-arterial vasodilators or angioplasty (9). Thus in general surgical or endovascular intervention is undertaken at the earliest opportunity for patients presenting in good clinical grade (WFNS grades 1-2) (7). For patients presenting in poor clinical grade (WFNS grades 3-5), surgical intervention is delayed for at least 10 days or more, to allow for risk of cerebral vasospasm to decrease and the clinical grade of the patient to improve. Resuscitation techniques, neuroprotective ventilation and use of external ventricular drainage may be employed in specific cases to help improve clinical grade (7). Endovascular management may also be delayed if the clinical picture so warrants, but on

most occasions if it is deemed amenable to coiling the procedure can be undertaken at any point to prevent re-bleeding.

Aneurysmal factors that play a role in deciding if neurosurgery or neurointerventional coiling is best suited include aneurysmal size, shape, aspect ratio, location, number of aneurysms and date of rupture (9). Patient factors such as age, clinical condition and co-morbid medical conditions also factor in decision making (9). Endovascular treatment by endosaccular coiling has been accepted as an alternative to surgical clipping for the treatment of ruptured and unruptured intracranial aneurysms (13). Due to new and recent endovascular techniques more aneurysms are amenable to coiling (13).

Cerebral embolization is defined as a therapeutic introduction of various medical substances or devices into the brain circulation to occlude vessels or vascular anomalies (aneurysms), either to arrest or prevent haemorrhages, to devitilize a structure such as a tumour by occluding its blood supply, to reduce blood flow to an arteriovenous malformation, to remodel a vascular wall or blood flow re-direction (14).

It is well known that the success of neurointerventional cases have a steep learning curve, and many studies aim to evaluate the feasibility and results of endovascular coiling as a first-line treatment for intracranial aneurysms. One such study is that of Lubicz et al. (2007), who found that endovascular techniques can be proposed for first line treatment of intracranial aneurysms in 87.3% of cases (13).

The advantages of embolisation include: shorter time of procedure, a reduction in surgical complication risks e.g. infection and intra-operative bleeding, with no need for brain compression and less side effects as a consequence thereof (15). Recanalisation of the aneurysm means that coiling is a less permanent treatment, requiring repeated interventions and is therefore its greatest disadvantage (15). While coil embolization has been shown to be safe and effective in the occlusion of aneurysmal sac, recanalization of the treated aneurysm, results in re-treatment in approximately 10-20 % of cases (16). Furthermore follow-up of intracranial aneurysms treated by embolisation with detachable coils is mandatory, to be able to detect and manage recanalization.

Throughout the nineties the majority of literature published regarding endovascular therapy for intracranial aneurysms consisted of single-centre, retrospective, self-reported series (17). With time confidence in the use of endovascular coiling techniques improved and as a result larger multicentered, prospective studies increased.

The International Study of Unruptured Intracranial Aneurysms (ISUIA) published in 1998 suggested that the risk of rupture in untreated aneurysms was lower than previously expected, and called into question the value of prophylactically treating unruptured intracranial aneurysms (17). In a further update of the study, the treatment related morbidity and mortality as evaluated at 1 year was as high as 12,6 % in

surgically treated cases and 9.8% in endovascularly treated cases (18).

Treatment strategies and outcomes for intracranial aneurysms are not only important for unruptured aneurysms but also for ruptured aneurysms. In 2002, the initial report of the International Subarachnoid Aneurysm Trial was published in Lancet. The main finding in this trial was that there were better outcomes for the endovascular coiling groups as compared to the surgical clipping 23.7% versus 30.6%, clinical outcomes defined by the Modified Rankin Outcome scale (19). The ISAT study observed that the rate of recurrent haemorrhage after clipping versus coiling is 0.063% versus 0.21% respectively. At 5 years the results of treatment equalized, amongst survivors 83% were independent in the coiling group and 82% in the clipping group (20). The patients randomised in ISAT represent a selected subgroup of patients with SAH seen in clinical practice, 88% were of good clinical status, 93% of the target aneurysms were 10 mm or smaller in diameter, and 97% of target aneurysms were in the anterior circulation, these three characteristics have historically been thought to predict a good neurological outcome after neurosurgical clipping hence the better neurological outcome after endovascular coiling in ISAT is thus noteworthy (21).

After the decision is made to treat an intracranial aneurysm, clinicians must choose between open surgery or endovascular therapy. Factors against coiling include: wide aneurysmal neck, size > 10mm,

aspect ratio (neck: dome) of 1:3, inadequate endovascular access, intraluminal thrombus, arterial branch occlusion, atheromatosis, fibromuscular dysplasia, middle cerebral artery aneurysms, stent implantation or balloon remodelling and age (22).

On the other hand factors against clipping include: neck: dome ratio < 1:3, age, difficult access, no efferent branches, high subarachnoid aneurysm grade, extended cranial base access, vasospasm, posterior circulation, poor medical condition (22).

In 1937 Walter Dandy performed the first surgical treatment of an aneurysm using a vascular clip designed by Harvey Cushing (23). In the post- ISAT era surgery was predominantly reserved for aneurysms in three types of groups which include: aneuryms unsuitable for endovascular treatment, recurrent aneurysms after initial coiling where further endovascular treatment is no longer an option and finally aneurysms treated surgically due to unavailability of the endovascular option (24). (Appendix C)

In the late 1990's Gugliemi and colleagues developed a device called the GDC – Guliemi Detachable Coil in which a soft platinum coil soldered onto a stainless steel wire was successfully delivered through a micro-catheter into the aneurysm sac (when the coil is properly positioned within the fundus a 1mA current is applied to the delivery wire i.e. electrolysis, (the catheter is removed as the coil is left in place) (14). The coil mass protected against rupture by buffering the haemodynamic stress against the fundus of the

aneurysm (14). In 1995 the US food and drug administration (FDA) approved the use of detachable coils (8).

Four types of coils exist namely bare platinum coils, coated platinum coils, biologically active coils, and radioactive coils. The stainless steel, platinum or titanium wire is visible via X-ray and should be flexible enough to conform to the aneurysm shape (14). Variations on endovascular treatments include, Detachable coil placements (coils vary in strength shape and size), detachable coil placements with temporary balloon assistance, detachable coils and intravascular stent placement, liquid embolic agent injection, occlusion of parent vessel and detachable coil placement in a remnant aneurysm after partial clipping (8).

Performed in a special angiography suite by Neuro-surgeons or Neuro-radiologists, general anaesthesia is used in all patients, access through the femoral artery, via 6F or 7F sheath and full heparinization with activated clotting times of 300 seconds (25). Heparinization is achieved and maintained as the guiding catheter is positioned upstream in the appropriate feeding vessel and initial feeding runs are performed. Coils are then detached into the aneurysmal sac under fluoroscopic guidance (25). The positively charged platinum theoretically attracts the negatively charged blood elements such as white blood cells, red blood cells platelets and fibrinogen thus inducing intra-aneurysmal thrombosis (16). The mechanism of healing in coiled intracranial aneurysms

during molecular and histopathologic studies suggest that from day zero to day seven, a fibrin layer covers the coils, macrophage invasion is seen in the coil periphery, unorganised thrombus surrounds the coils and a thin incomplete fibrin layer is seen at the aneurysm neck (16). At one to two weeks increased fibrin coating of the coils, with macrophages in the periphery and myo-fibrolast invasion are seen; a thin fibrin layer at the neck with endothelialisation at the neck periphery and along the coil is evident (26).

Two weeks to one month shows increased myofibroblast invasion, the thrombus is more organised and macrophages in the aneurysm periphery is visible (26). At one to three months decreased cellularity occurs within the aneurysm, myofibroblasts and macrophages die via apoptosis and the neck is further endothelialized (27). At three months plus, the aneurysm dome is acellular and vascularised, and connective tissue is apparent in the aneurysm dome. Several months following embolization the aneurysm is excluded from the parent vessel by formation of neo-intimal layer (27).

After one year the coil is generally incorporated into the aneurysm wall and the aneurysm dome is filled with vascular fibrous connective tissue. Thus suggesting that mechanism of aneurysm healing following coil embolization is similar to the well-studied and well understood wound-healing process (28). Yamaguchi further states that an important difference in the healing process of a coiled aneurysm vesus wound-healing is that the extensive collagen

matrix seen following wound healing is not seen following coil embolization (28).

2.5) Complications of Endovascular Coiling

Complications of endovascular treatment of cerebral aneurysms include: intra-procedural complications, re-bleeding, vessel rupture, thromboembolism, inability to coil, arterial access complications, vasospasm, shunt dependant hydrocephalus, aneurysm re-growth or recanalisation and miscellaneous (25). Endovascular unruptured aneurysm treatment is generally safe, but patients with ruptured aneurysm presents a unique set of problems i.e. the vessels are more friable, blood flow more compromised, intracranial pressure measurement issues occur. Anti-coagulant or anti-platelet agents are necessary for endo-vascular safety but are hazardous in the face of unruptured aneurysm management (29).

In Ross et al. data gathered on 118 patients undergoing 126 endovascular treatments found that the vessel rupture with no sequela was at 6% and vessel rupture with sequela 2%, while thromboembolism with sequalae was 6% and there were no bleeding or re-bleeding cases. Vasospasm after SAH remains amongst the leading causes of delayed morbidity and mortality in patients with ruptured intracranial aneurysms (3). The onset of cerebral vasospasm begins on day 3 and peaks between 7-14 days after the subarachnoid haemorrhage. Up to 70 % of patients will develop radiographic signs of vasospasm and approximately 30 % will develop clinical vasospasm (12). The incidence and severity of vasospasm is related to the amount and duration of perivascular hematoma. In Mahmoud et al.

131 patients with 168 aneurysms were treated and the incidence of angiographic vasospasm was 17.4% in coiling versus 45.4% in clipping. Shunt-dependant hydrocephalus was reported to range from 6-7% (29).

Park et al. reports 6% procedure related complications in 180 patients who underwent 131 procedures for 118 ruptured aneurysms and 79 procedures for 72 unruptured aneurysms (3). One of the limitations of endovascular coiling is the low incidence of total aneurysmal occlusion and, hence recanalisation with subsequent aneurysmal re-bleeding (3). Most aneurysm recanalization occurring within the first three months of treatment. In Taha 2006, Murayama et al. is quoted as having a 55% total occlusion of aneurysm rate, a 35.5% residual neck and 3.5% incomplete occlusion rate as compared to Henkes et al. reporting 65.8%, 20.7% and 5.5% respectively (3).

2.6) Outcomes of Endovascular Coiling

More and more patients survive aneurysmal SAH with case fatality decreasing by 17% in absolute terms over the past three decades, and incidence the remaining relatively stable at 9/100000 of the population (31). Life expectancy is shortened for patients who survive aneurysmal SAH, but various cognitive deficits and mood disorders are some of the problems still exhibited (10). Two-thirds of aneurysmal SAH survivors gain functional independence, half have cognitive impairments, half are dissatisfied with life, and only a third resume the same work as before the event (31). Although the above indicates outcomes for aneurysmal SAH that is treated by both clipping and coiling, it is

the follow up reports by the ISAT trial that gives us more tailored outcomes due to endovascular coiling. The final year results in Molyneux 2005 paper reinforce preliminary findings, that endovascular coiling compared to neuro-surgical clipping for ruptured intracranial aneurysms that were anatomically suitable for either procedure, leads to significant reduction in relative risk of death or dependency 23.9% (12.4-33.9%). This equates to an absolute risk reduction of 7.4% (3.6-11.2%) which is equivalent to 74 patients avoiding death or dependency at 1 year for every 1000 patients treated (18). Once the aneurysm has ruptured, one third of patients die and two thirds survive, with 50% of survivors leading independent lives. Endovascular treatment has a higher safely profile and complication risk lower than that of surgery, contributing significantly to better outcomes.

2.7) Further Application

As the outcomes with endovascular coiling when treating intracranial aneurysms are shown to be better, more technically challenging aneurysms are being treated via coiling. An example of this includes the management of blister like aneurysms as high intra- and post-operative bleeding has been reported during surgical clipping of these aneurysms, indicating difficulties arising in the operative management of blister like aneurysms (32). The re-bleeding risk for blister aneurysms is higher than for saccular aneurysms, and perioperative haemorrhage can be life threatening, and significant (32). Endovascular

management is also technically challenging because of the weak nature of blister like aneurysms and small size of the aneurysm with a broad neck. A stent placement is essential in most cases so as to retain coils within the aneurysm sac, however endovascular management using single/overlapping stent and, if possible coil placement, is technically safe and feasible in blister aneurysms (32).

Endovascular coiling can also be applied to the management of large and giant intracranial aneurysms (>10mm) that have a poor natural history and usually warrant intervention. A study from Japan reports an annual rupture rate of 4.37% for 10- 24 mm aneurysms and 33.4% for aneurysms larger than 24 mm (33).

Treatment options for large and giant aneurysms include open surgery or endovascular techniques. Surgical treatment is often challenging and can be associated with significant morbidity (33). Available endovascular modalities include endosaccular coiling with or without stent/balloon assistance, endovascular parent vessel deconstruction, Onyx HD-500 (ev3, Irvine, California) embolisation and recently, flow diversion. Chalouhi et al go on to show in their study that the coiling of large and giant aneurysms has a reasonable safety profile with good clinical outcomes but with aneurysm recanalization and retreatment rate of 39% and 33% respectively. Overall stent assisted coiling of giant aneurysm has a lower recurrence and re-treatment rate (33).

2.8) Conclusion

Bairstow et al. compared hospital costs for ISAT patients enrolled at 2 hospitals in Perth, Western Australia. They found that hospital costs were lower for endovascularly treated patients than for surgically treated patients. Although the endovascular procedures were more expensive in terms of the cost of consumables, the total costs were lower than for surgically treated patients because of the lower staffing costs and lower costs of post procedure hospitalisation (34). However B. Hoh et al in their model demonstrates that length of hospitalization is directly associated with hospital costs. Thus, despite a shorter length of hospitalization with endovascular treatment compared with surgery, endovascular treatment was still associated with significantly higher costs to the hospital, because postoperative, in-hospital management of patients with ruptured aneurysms is similar whether they are treated with clipping or coiling. And in- hospital management of patients with unruptured aneurysms is shorter after coiling, thus showing that the higher hospital costs with coiling must be attributable to the higher device cost of coils than clips (35). The advantages of coiling over clipping would be better realized if the cost of coils could be comparably reduced to that of clips.

Initially endovascular treatment was used in patients who were thought to be poor candidates for surgical treatment such as patients with severe neurological deficits, aneurysms of the posterior circulation or in cavernous segment of internal carotid artery, age over

75, patients presenting 3-7 days after aneurysm rupture or with active intracranial vasospasm. Following the ISAT study the modality of treatment of aneurysmal SAH has changed in favour of endovascular therapy in many units (36). Dasaut (2012) in his article states that the process of choosing between these two options should not only be made on a case by case basis but more in line with properly controlled and conducted randomized trials to determine the optimal treatment modality for intracranial aneurysms. However, this thought process for clinicians can only be made a reality if both treatment options are available to them in the holistic treatment of patients with intracranial aneurysms.

Intracranial aneurysm research globally began to peak in 2002 after the ISAT study and followed a logistical growth model until 2008. The major contributors in descending order include: United States of America, Japan, Europe, Australia and Canada (37). China has increased its intracranial aneurysm research rate and by 2012 became the third largest contributor to the pool of research on intracranial aneurysms (37). Research regarding intracranial aneurysm treatment still remains poor within the African continent despite a fair amount of patients that present with subarachnoid haemorrhage. Research projects such as this will enable us to begin to contribute to international experience and become part of the global the dialog regarding the management of intracranial aneurysms.

Chapter Three –Methodology

3.1) Introduction- Research Design

The intention of this research was to describe the characteristics of all aneurysmal coiling cases done at CMJAH over a two year period. A quantitative research design was used, in which the content of hospital records regarding the coiled cases were collected and analysed. Statistical procedures are used to analyse the data. Once the researcher has measured relevant variables, the observations on the data are transformed statistically to help the researcher describe the data more succinctly and make inferences about the characteristics of the populations on the basis of the data from the chosen sample (38).

Quantitative research is:

- a formal, objective, systematic process for obtaining quantifiable information about the world;
- presented in numerical form, and analysed through the use of statistics;
- used to describe and to test relationships;
- used to examine the cause-and-effect of relationships (38).

Quantitative researchers attempt to remain detached from the study, and from the sample (in studies where the sample is made up of human beings) it strives to maintain objectivity trying not to influence it with their own personal values, feelings, and experiences (39).

This is because quantitative researchers believe that researcher involvement in the study could bias it. By 'bias it', they mean that they do not want to sway the study towards the perceptions and values of the researcher, rather than allowing the hard scientific facts to hold sway (39). Quantitative research aims to quantify data and generalize results from a sample to the population of interest in order to measure the incidence of various views and opinions in a chosen sample. This enables a researcher to cast a wide net for a large number of cases representing the population under review. The raw data can be obtained from a variety of sources e.g. questionnaires, data bases etc. Statistical data is usually represented in the form of tabulations. Findings are conclusive and usually descriptive in nature and can be used to recommend a final course of action.

3.2) Research instruments, sample and analysis

Research instruments used to gain the relevant information about all the coiling cases was found in patient files kept as hard copies/micro fish and the radiological reports. The patient's details were obtained and then added to a research data collection sheet. The purpose of using both the radiological reports and the patient's files was to gain detailed information that is more reliable and valid. Both sets of records allowed the researcher to gain the information that was needed to be able to fulfil the objectives of the study.

The data collected was divided into patient demographics and aneurysmal characteristics. The patients' age, sex, and co-morbidities were detailed. Dates of admission were subtracted from dates of aneurysmal rupture, and hence the duration of time from rupture to admission was determined. Dates of discharge after coiling was subtracted from the date of coiling and the duration of time the patient had to wait in hospital was calculated. The clinical condition on admission was described in the form of World Federation of Neurosurgeons Grade for subarachnoid haemorrhage, while the patients clinical condition on discharge was assessed using the Rankin Disability Index.

Patients that were direct admissions or transfers were also recorded. Specifics about the aneurysms anatomy, size and location was obtained from the radiological reports in addition to the number of coils used in treating the aneurysm and the duration of the coiling procedure. All complications ranging from none, re-rupture, mechanical obstruction, vasospasm, thrombo-embolic event , hypotension, hypertension blood loss, ventilator issues were recorded using further information from anaesthetics records and radiological records kept after the coiling procedure. The pool from which this data was collected included all patients who had sustained a subarachnoid haemorrhage and were deemed sufficient to fit the criteria for an endovascular procedure. This sample is significant of a general population as aneurysmal subarachnoid haemorrhage is a rather small entity with neurosurgical pathology affecting 6-8/100000 of the population with a

significant amount of patients qualifying for treatment via endovascular coiling (34). The researcher arrived at this sample population of sixty-two consecutively coiled cases after the newly established endovascular unit began at CMJAH hospital. The data collected regarding the management of aneurysms via endovascular coiling is robust, concrete and was not influenced by collector bias, as it is purely factual. In addition, the characteristics of the data collected is in keeping with many studies of this nature where a single centre retrospective series of endovascular cases is done, in a unit that is newly established.

3.3) Limitations

As envisaged by the research protocol the major limitation of this study was the poorly kept hospital records. During the time in question the CMJAH hospital records were kept in a rudimentary micro-fish archiving system. This meant that often the files that were provided were inadequate and lacked significant details. The radiological data base was also scanty and poorly kept, as most radiological reports were in hard copy and barely legible at times. In addition to the lack of information, the radiological details were fairly non-specific and often needed cross referencing with anaesthetic charts, especially in determining durations of the procedures.

As with any research a larger sample size yields information for a broader generalisation. Keeping in mind that aneurysm pathology in itself has a small incidence within the population at large and that this

has been a treatment modality in its infancy at the CMJAH, which is technically complicated and time consuming, this sample size will more than adequately provide a fair number for the descriptive nature of the study. As is in keeping with sample sizes quoted in many research studies regarding intracranial aneurysms.

3.4) Ethical Considerations

The commencement of retrospective data collection was done after the approval by the Human Research Ethics Committee (Medical), at the University of the Witwatersrand. In addition permission by the CMJAH CEO was given, to be allowed access to patient files. All data collection sheets have been in the safe keeping of the researcher.

3.5) Conclusion

A retrospective review of patient files to gain data regarding intracerebral cases that were coiled was conducted. The data in its raw form was entered into data collection sheets and later captured for statistical analysis. Although limitations in a retrospective review of data are apparent, a fair amount of rich and accurate data was gathered to provide a descriptive analysis of the coiled cases performed at CMJAH.

Chapter 4- Findings and Analysis

4.1) Introduction

This chapter aims to bring together the research results obtained from the hospital and radiological records to fulfil the objectives of the descriptive study. The results have been compared to international standards and the advantages and disadvantages of endovascular coiling of intracranial aneurysms as a first-line treatment modality have been brought to light.

4.2) Background

Since the publication of the ISAT, there has been a paradigm shift in the treatment of cerebral aneurysms in the USA, and the world over. Cerebral aneurysm coiling has surfaced as the predominant treatment modality, not only for subarachnoid haemorrhage, but also for elective cases, increasing the total number of aneurysms treated in recent years (40). Aneurysms can be either coiled or clipped following subarachnoid haemorrhage the goal is complete obliteration of the aneurysm. The choice of coiling versus clipping should be a multi-disciplinary decision based on patient and aneurysm characteristics. Coiling if possible has better outcomes in terms of disability at 1 year according to the ISAT trial. The ISAT trial included aneurysms with these characteristics: good grade, ICA or ACA aneurysm, amenable to both coiling and clipping, <10 mm diameter. Stenting is riskier than either, and is not generally recommended.

The advantages of coiling include lower cumulative cost profile, less need for an invasive craniotomy, resulting in an increased survival and decreased morbidity. Less vasospasm occurs and intra-arterial vasoactive agents can be given if vasospasm does occur (40). Coiling is better tolerated for posterior circulation aneurysms, the elderly and patients with poor neurological grade (40).

The disadvantages of coiling are the requirement of extensive training, as endovascular coiling is done either by a neurosurgeon or by an interventional neuroradiologist. The interventional radiologist undergoes extensive training (3-5 years) in both radiology and interventional (invasive) procedures involving the brain and spinal cord. All neurosurgeons that perform endovascular coiling have undergone additional training in endovascular techniques in addition to full neurosurgery training (5-7 years of residency) (41). Coiling requires anticoagulation and has a risk of rupture and not all aneurysms can be coiled. Most of all the cost of the coils and equipment is a great disadvantage (43). Patients with aneurysmal SAH who were coiled had higher charges than patients who could be treated by clipping, showing that he benefits of apparent decrease in length of stay in the endovascular group were offset by higher procedure price and cost of consumables (43).

However, endovascular treatment has been confirmed as the treatment of choice for intracranial berry aneurysms, initial doubts on the part of microvascular neurosurgeons were addressed by the ISAT, even

though the durability and long-term efficacy of coiled aneurysms have been questioned (42).

4.3) Results

a) Introduction and baseline description of the study participants

The study sought to estimate the success rate of coiled patients along with describing common complications associated with coiling and the co-morbidities associated with the aneurysm cases that underwent coiling.

The sample size consisted of 62 cases that underwent a coiling process at Charlotte Maxeke Johannesburg Academic Hospital. Table 1. below provides a detailed description of the demographic and clinical characteristics of the patients. Of the 62 cases that were coiled, 58% were females against 42% of males. The overall age of the patient was 47 with a standard deviation of about 14 years of age. Figure 1, presents the distribution of coiled patients by gender.

With regard to ethnicity, black patients represented about more than two third (69%) of the study analysed and other ethnicities the remainder.

In terms of hospital referral routes, most of the patients (47.27%) were admitted directly from home and were not referred by any hospital. Of the 62 patients, only 20% were referred by Helen Joseph Hospital.

Table 1: Baseline characteristics of the coiled patients at Charlotte Maxeke Johannesburg Academic Hospital (2012 - 2013)

Characteristics	N=62
Gender	
Male	26 (41.94)
Female	36 (58.06)
Age (mean, std)	46.70 (14.49)
Race	
Black	43 (69.35)
White	11 (17.74)
Coloured	5 (8.06)
Other	3 (4.84)
Referral Hospital (n=55)	
Direct	26 (47.27)
HJH	11 (20.00)
Other	18 (32.73)
WFNS Grade on Admission	
Intact Aneurysm	7 (11.29)
15	26 (41.94)
13 – 14 (-)	12 (19.35)
13 – 14 (+)	9 (14.52)
7 – 12	8 (12.90)
Internal Carotid Artery	
ICA Bifurcation	5 (8.06)
Anterior Choroidal Segment	1 (1.61)
Posterior Communication Artery Segment	20 (32.26)
Ophthalmic Segment	1 (1.61)
Cavernous Segment	3 (4.84)
Anterior Cerebral Artery	
A_1 Segment	4 (6.45)
Anterior Communication Artery	11 (17.74)
Distal ACA	3 (4.84)
Middle Cerebral Artery	
M_1 Segment	7 (11.29)
Posterior Cerebral Artery	
Basilar Artery	5 (8.06)
Posterior Inferior cerebellar Artery	2 (3.23)
Vertebral Artery	1 (1.61)
Coiling complication	
No Complication	49 (79.03)
Obstruction, hooking, clinking &	1 (1.61)

dislodgement	
Vasospasm	7 (11.29)
Thromboembolic event	5 (8.06)
Comorbidities	
Hypertension	18 (29.03)
Diabetes	3 (4.84)
RVD	7 (11.29)
Risk factors	
Smoking	13 (20.97)
Alcohol	5 (8.06)
Others (previous aneurysm, family history)	14 (22.58)
Coiling outcome	
Alive	57 (91.94)
Death	5 (8.06)

Further results from table 1; reveal that the proportion of successful coiled cases was 91.94% who survived against 8.06% who died.

In addition, table 1 also shows that on admission to the hospital only 11% had intact aneurysm, whereas 41.29% presented with a GCS score of 15. In terms of complications, the most prevalent complication was vasospasm representing 11.29% of the patients, followed by thromboembolic events 8.06%. The most common comorbidity was hypertension, prevalent among (29%), whereas diabetes was least common (5%).

In terms of risk factors, 21% of the patients reported smoking, whereas 8% reported alcohol use.

On the other hand, of the 62 cases coiled only 8.06% died against 91.94% who survived but developed comorbidities. Of the 57 who survived, 34 (59.65%) did not have any comorbidities. However, 5 had two comorbidities (hypertension and diabetes, or

hypertension + RVD); 18 (31.58) had at least one of the comorbidities.

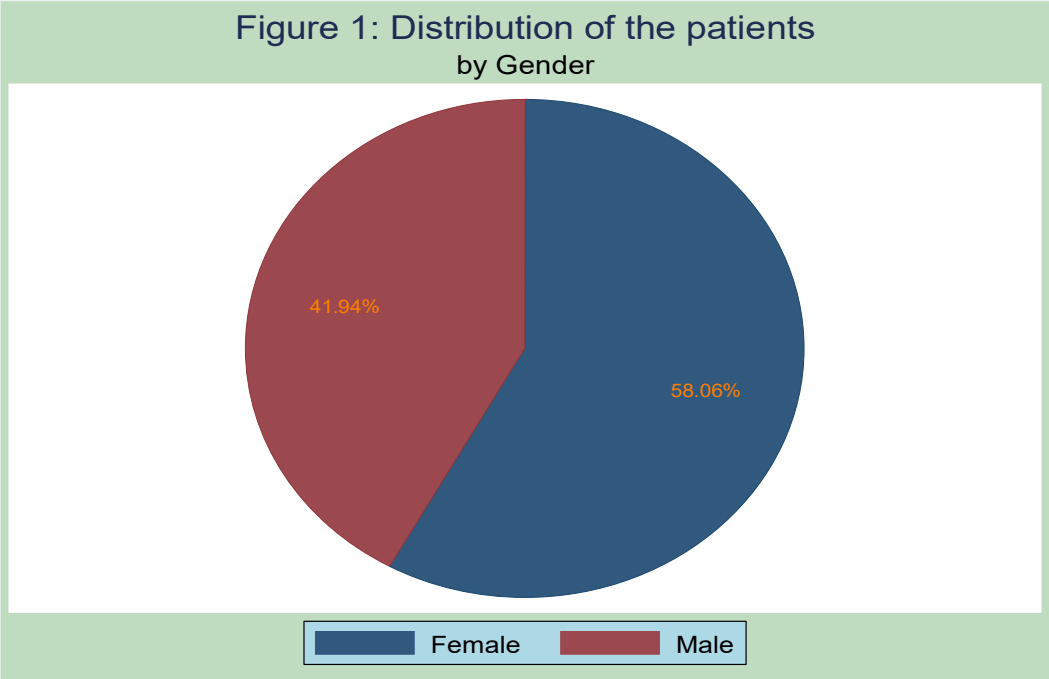
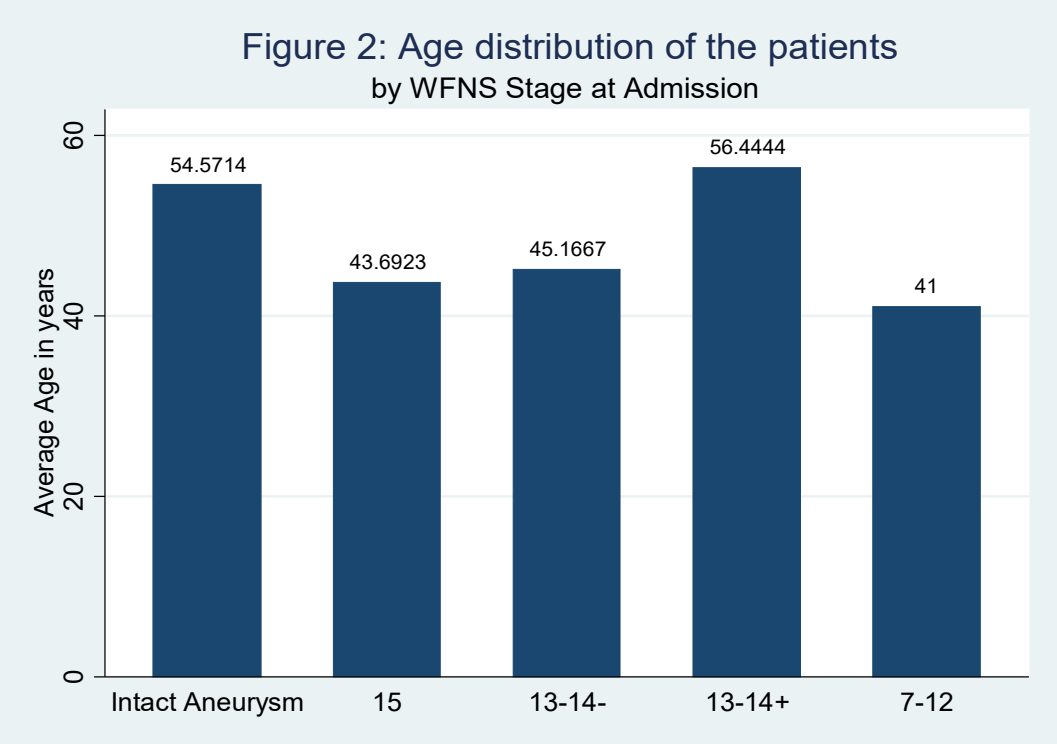


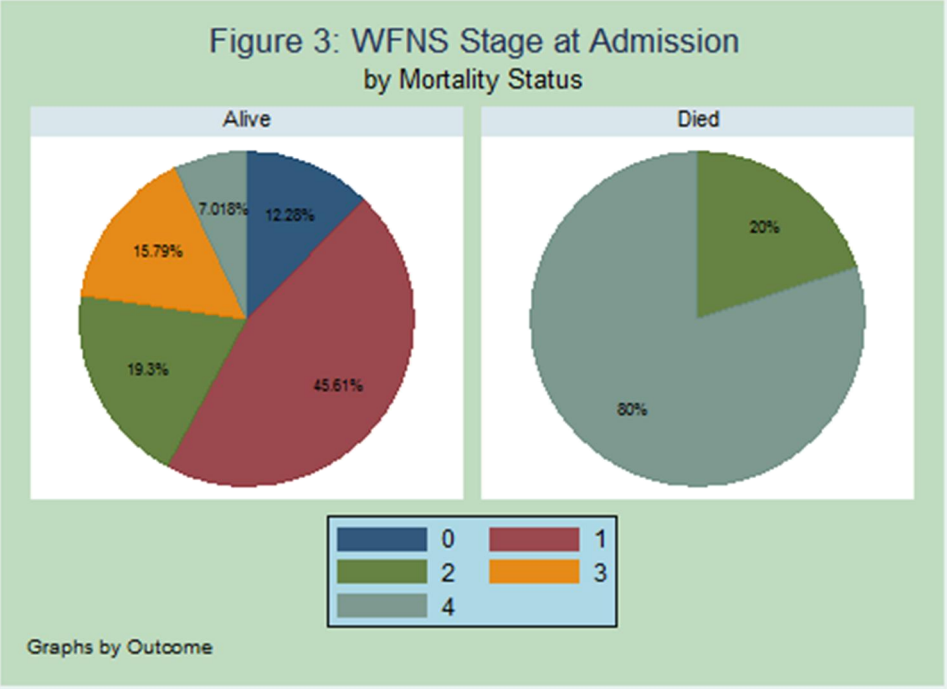
Figure.2 below shows the age distribution of the patients by WFNS grade at presentation, suggesting a marginal association (p-value: 0.07) between age at presentation and the WFNS stages. Evidence seems to support the existence of a relationship between age and WFNS stages. Patients presenting with grade 3 (GCS 13 – 14) were relatively older (56 years), followed by patients with intact aneurysm (55 years). The youngest patients were on average at grade 4 (GCS 7 – 12).



b) Association between demographic, clinical characteristics of the patients and mortality status

Objective two of the study sought to describe the demographic, clinical criteria, aneurysm location and size in association with mortality status of the patients. Other risk factors including previous aneurysm and family history showed a marginally significant association with mortality status (see figure 3 below).

In analysing the mortality cases, of the 5 patients who died, 80% presented to hospital with a WFNS stage 4 (GCS 7 – 12). This supports the association (0.001) between WFNS at admission and mortality status as presented in figure 3. The WFNS on admission stages of those patients who survived were distributed across a range of grades.



In addition, a significant association between aneurysm size and mortality status of the patients was found. The size was relatively bigger (average size and std: 3.2 ± 0.45 mm) among those who died compared to those who survived (average size and std: 1.85 ± 0.75) (figure 4).

These two variables, WFNS stage at presentation and aneurysm size were the only significant predictors of mortality among coiled patients.

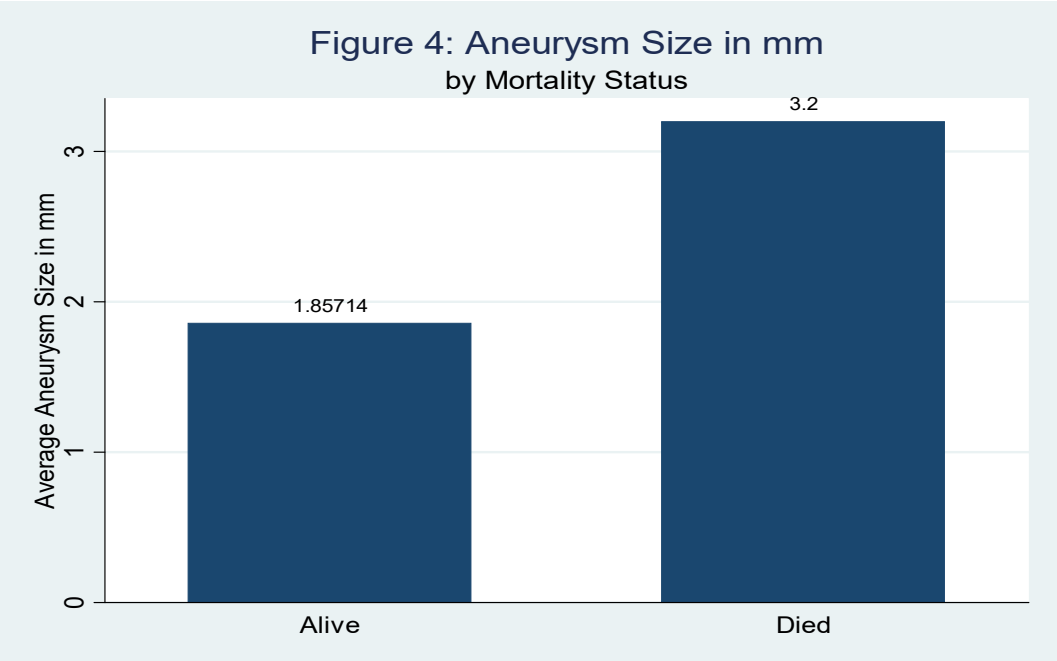


Table 2. below presents in more detail the results on different associations investigated.

Table 2: Association between patient's characteristics and Coiling Outcome

Characteristics	Outcome Status		p-value
	Death	Alive	
Gender			
Male	3 (11.54)	23 (88.46)	0.64
Female	2 (5.56)	34 (94.44)	
Age (mean, std)	50.8 (11.30)	46.35 (14.76)	0.51[t]
Race			
Black	2 (4.65)	41 (95.35)	0.15
White	1 (9.09)	10 (90.91)	
Coloured	1 (20.00)	4 (80.00)	
Other	1 (33.33)	2 (66.67)	
Referral Hospital (n=55)			
Direct	1 (3.85)	25 (96.15)	0.53
HJH	1 (9.09)	10 (90.91)	
Other	2 (11.11)	16 (88.89)	
WFNS Grade on Admission			
Intact Aneurysm	0 (0.00)	7 (100.00)	0.001
15	0 (0.00)	26 (100.00)	
13 – 14 (-)	1 (8.33)	11 (91.97)	
13 – 14 (+)	0 (0.00)	9 (100.00)	
7 – 12	4 (50.00)	4 (50.00)	
Time to Admission (mean, std) Days	3.6 (2.61)	5.77 (10.57)	0.65[t]
Time to coiling (days)	14.4 (23.44)	9.38 (11.69)	0.41[t]
Time to discharge (days)	00(00)	3.55 (5.58)	
Internal Carotid Artery			
No ICA located	4 (12.50)	28 (87.50)	0.36
ICA Bifurcation	1 (20.00)	4 (80.00)	
Anterior Choroidal Segment	0 (0.00)	1 (100.00)	
Posterior Communication Artery Segment	0 (0.00)	20 (100.00)	
Ophthalmic Segment	0 (0.00)	1 (100.00)	
Cavernous Segment	0 (0.00)	3 (100.00)	
Anterior Cerebral Artery			
No ACA located	3 (6.82)	41 (93.18)	0.60
A_1 Segment	0 (0.00)	4 (100.00)	
Anterior Communication Artery	2 (18.18)	9 (81.82)	

Distal ACA	0 (0.00)	3 (100.00)	
Middle Cerebral Artery			
No MCA located	4 (7.27)	1 (14.29)	0.46
M_1 Segment	51 (92.73)	6 (85.71)	
Posterior Cerebral Artery			
No PCA located	4 (7.41)	50 (92.59)	0.51
Basilar Artery	1 (20.00)	4 (80.00)	
Posterior Inferior cerebellar Artery	0 (0.00)	2 (100)	
Vertebral Artery	0 (0.00)	1 (100.00)	
Coiling complication			
No complication	3 (6.12)	46 (93.88)	0.21
Obstruction, hooking, clinking & dislodgement	0 (0.00)	1 (100.00)	
Vasospasm	2 (28.57)	5 (71.43)	
Thromboembolic event	0 (0.00)	5 (100.00)	
Comorbidities			
Hypertension			
Yes	0 (0.00)	18 (100.00)	0.31
No	5 (11.36)	39 (88.64)	
Diabetes			
Yes	0 (0.00)	3 (100.00)	
No	5 (8.47)	54 (91.53)	1.00
RVD			
Yes	0 (0.00)	7 (100.00)	1.00
No	5 (9.09)	50 (90.91)	
Risk factors			
Smoking			
Yes	2 (15.38)	11 (84.62)	0.28
No	3 (6.12)	46 (93.88)	
Alcohol			
Yes	1 (20.00)	4 (80.00)	0.35
No	4 (7.02)	53 (92.98)	
Others			
Yes	3 (21.43)	11 (78.57)	0.07
No	2 (4.17)	46 (95.83)	

Note: p-values in the table refer to Fisher exact unless otherwise indicated

[t] refers to independent t-test for equality of means

Results from Table 2 above, suggest that death was a rare event among coiled patients. Few variables had a statistically significant association with mortality, except aneurysm size and initial SAH grade. Aspects such as duration of time taken to admission and time to coiling may have been significant if sample size allowed. In addition other variables such as race (p-value: 0.15) and other risk factors including previous aneurysm and family history (p-value: 0.07) might also have shown significant association if the sample size considered was large enough.

Time to admission was up to 6 days for cases that survived while only 3 days for cases that died. Time to coiling after admission was 9 days is successful cases and 14 days in cases that died. Time to discharge after coiling was 3.55 days, discharge was either to a secondary facility or home and is not reflected.

Figure 5, represents the complication percentage of cases. As most coiling cases were successful with no complications noted in up to up 79.03%. Vasospasm was the most common complication while technical problems during coiling procedures the least.

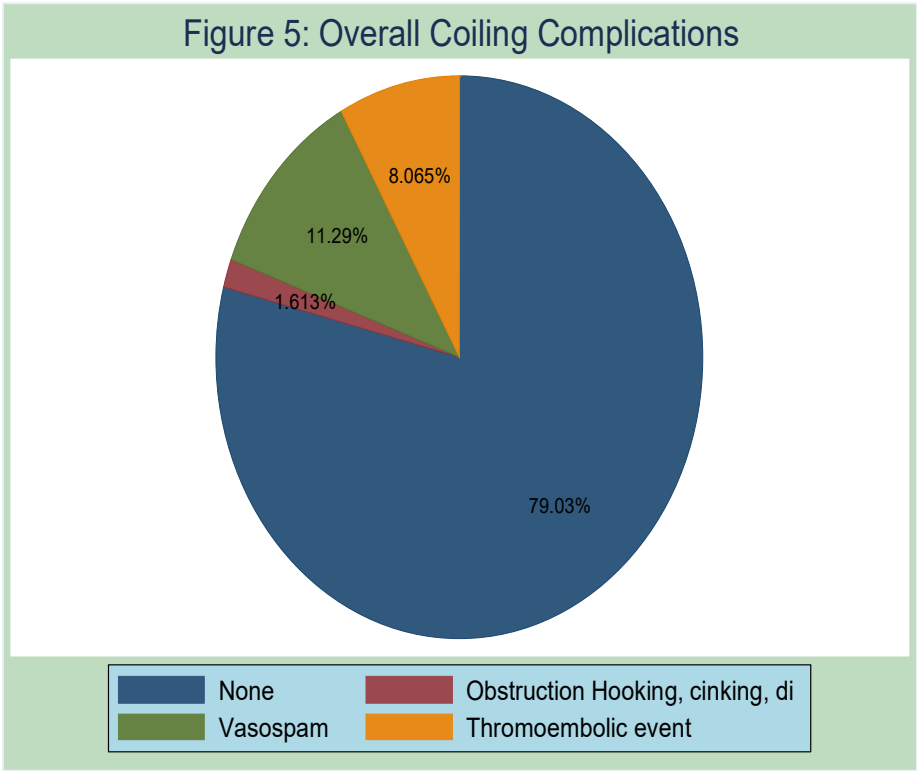


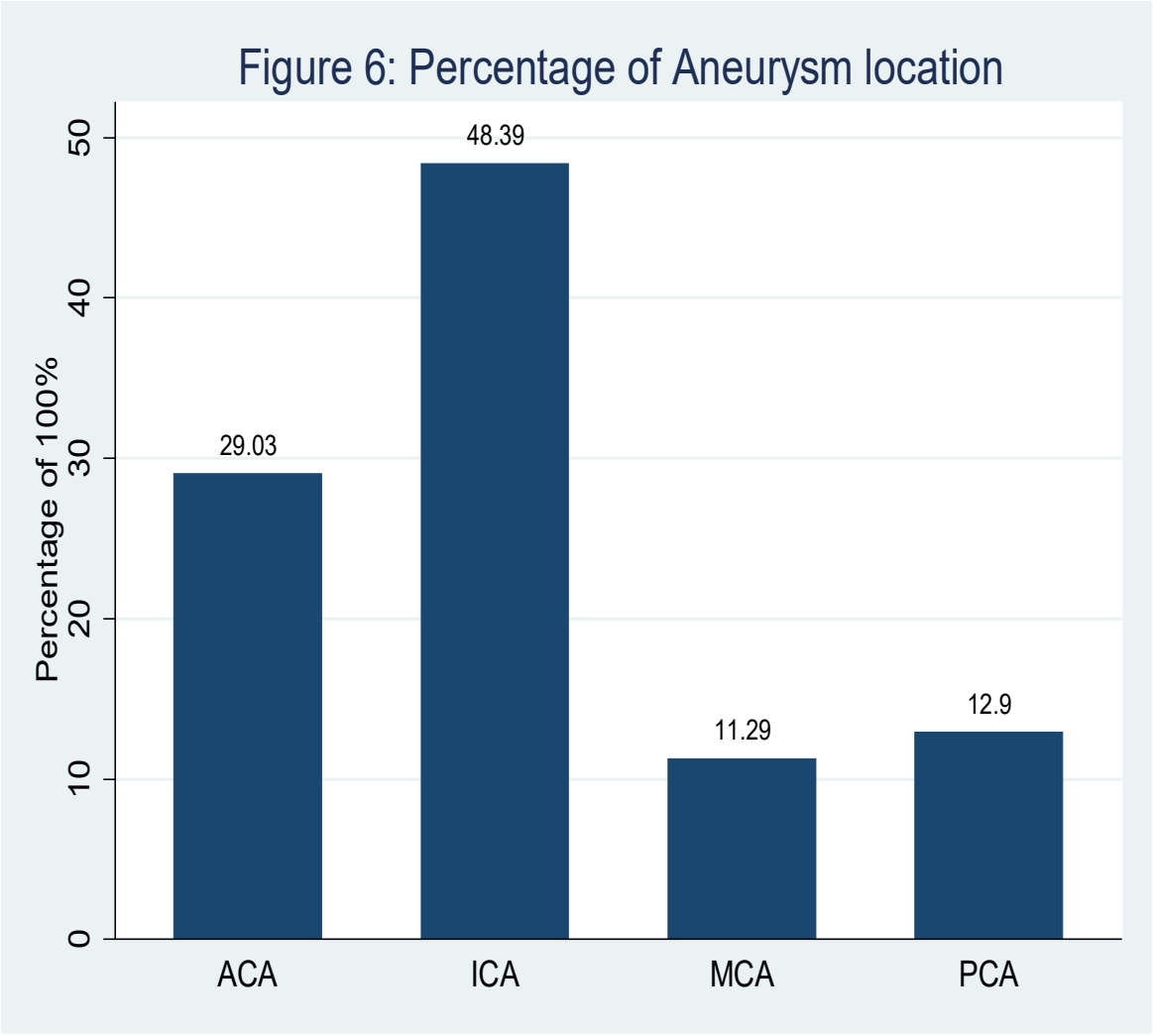
Table3. Illustrating Aneurysm size and Location

Location		Aneurysm size			
	N	0 – 0.5 mm	0.5 – 10 mm	10 – 25 mm	25+ mm
ACA					
A1 Segment	4	2 (50.00)	1 (25.00)	1 (25.00)	0 (0.00)
Ant Comm Artery	11	3 (27.27)	5 (45.45)	3 (27.27)	0 (0.00)
Distal ACA	3	3 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)
MCA					
M1 Segment	7	3 (42.86)	0 (0.00)	4 (57.14)	0 (0.00)
PCA					
Basilar Artery	5	1 (20.00)	2 (40.00)	1 (20.00)	1 (20.00)
Post Inferior Cerebellar Artery	2	0 (0.00)	2 (100)	0 (0.00)	0 (0.00)
Vertebral Artery	1	1 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)
ICA					
ICA bifurcation	5	1 (20.00)	1 (20.00)	3 (60.00)	0 (0.00)
Anterior Choroidal segment	1	0 (0.00)	1 (100.00)	0 (0.00)	0 (0.00)
Post comm artery segment	20	8 (40.00)	9 (45.00)	3 (15.00)	0 (0.00)
Ophthalmic segment	1	0 (0.00)	0 (0.00)	1 (100.00)	0 (0.00)
Cavernous segment	2	2 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)

Table 3.

Of the 11 Ant comm artery aneurysms 5 had a size between 5-10mm. The most common location for the ICA aneurysm was the post comm segment (N-9) that had the size of 5-10mm.

Figure 6. Illustrates the most common aneurysm location that underwent coiling is ICA: posterior communicating segment.



4.4) Analysis

SAH incidence varies widely around the world, depending on geographical region, gender, ethnicity (9). Overall, the SAH incidence is higher in women, but differs between ages; men are predominant in the first three decades of life, then the incidence is equal by the fifth decade, and thereafter women have a slightly higher incidence (9). A 2.1 times higher SAH incidence has been found in black people compared to white people (9). The results shown in this study echo this.

Modifiable risk factors of SAH include smoking (odds ratio of 3.2), excessive alcohol consumption (odds ratio 1.5), exercise (relative risk ratio of 0.5) and hypertension (odds ratio of 2.9), the importance of these modifiable risk factors is emphasized by studies suggesting they cause 66% of haemorrhages, compared to only 10% that are attributed to genetic susceptibility (43). In this study 31% of patients had hypertension and 21% of patients were smokers. An important risk factor that was identified was that of RVD positive cases, in 7 patients. Patients infected with HIV appear to be prone to developing vasculitis with a reported incidence of 23% , a large range of pathologies have been described affecting different vessel sizes in most organs and there are many reasons for patients with HIV and AIDS to present with neurovascular disease(45). As coiling is seen to be a modality used in complicated aneurysmal cases, HIV associated aneurysms is yet another area of utility especially

within a South African context. Even though this was not a key area of this research it may inform areas for further research.

The vast majority of the treated IA were located in the anterior circulation specifically ACA (29.0 %), ICA post comm artery segment (48.3%), MCA (11.2%) and PCA (12.9%) in case of ruptured and unrupured aneurysms (Figure 6). Ross et. al showing results, ACA (24 %), ICA (59%) MCA (1%) and PCA (14%) in case of ruptured aneurysm and unruptured aneurysms in data gathered on 118 endovasculary treated cases. As with ISAT trial (95%) of aneurysms are located in the anterior circulation (18). This shows that our study also has a similar distribution of aneurysms in each location as compared to these studies.

Regarding the severity of the SAH, it is as been shown in many studies regarding most the management of intracranial aneurysms that the initial grade of the SAH is a predictor of outcome irrespective of the modality used, i.e. coiling or clipping (44). In ISAT trial 88% of patients of good clinical grade (WFNS 1-2) (18). As with this study more than 50% of the study cases had a GCS of 13 or better and remained this way after coiling. While 80% of the cases who demised had been admitted with GCS grade of less than seven and hence higher WFNS grade.

With regard to aneurysm size and location it is well known the most aneurysms that are amenable to coiling are in the anterior circulation and range from 5-10mm as seen in ISAT. In yet another large scale trial

by Wilinsky in 2009, with cohort of 391 ruptured aneurysm, 34 % were ant comm location and 78% in post comm, MCA territory was 18 % and post circulation 31%. A total of 62% had size of 5-15mm. Willinsky also shows a good outcome score of 74%. In this study similar proportions of cases for ACA territory with a percentage of 29.03%, ICA 48.39%, and MCA 11.29% were sited. However our PCA 12.9% percentage is much lower, this is perhaps due to the higher mortality of these cases even before admission. In keeping with these studies the average size of aneurysms coiled in this study was a percentage of 72% in 5 – 10mm range.

In view of the complications of coiling direct comparison between coiling and clipping procedures is difficult, particularly as some aneurysms/ haemorrhages are considered more suitable for neurosurgery (e.g. wide-necked aneurysms) rather than endovascular surgery and vice versa (44). Patients who undergo endovascular (coiling) and neurosurgical (clipping) treatments are at risk of unintended consequences, as is the case with all medical procedures. Complications for both procedures are the same, although the frequency of complications differs (45). Maud et. al in a cohort of 45 patients showed the procedural and peri-procedural complications occurred in seven patients (15%), ranging from technical complications to severe thromboembolism and re-bleed.

The complication profile here in this study is more in keeping with that of Ross et al, with good coiling outcome in up to 70% of coiled cases, with no re-

bleeding, however there was a higher rate of vasospasm at 11%, whereas Ross reports none. Ross also has a thromboembolic rate of 6% where this study is up to 8%.

In general, surgical or endo-vascular intervention is undertaken at the earliest opportunity for patients presenting in good clinical grade (i.e. WFNS 1 or 2) (36). For patients presenting in poor clinical grade (i.e. WFNS grades 3-5) surgical intervention is delayed for at least 10 days or more to allow for cerebral ischaemia to settle and for the patient to improve in clinical grade (36). For patients presenting in poor clinical grade (i.e. WFNS grades 3-5) endovascular intervention can also be delayed for at least 10 or more days, however early embolization of patients who are ventilated can be done to prevent re-bleeds. Gnanalingham in his cohort of 117 patients goes on to show that there was a delay in obtaining an angiogram after admission of up to 2 days as more cases are now chosen for coiling and more work load on the neuro-interventional units. In this study there was also a delay of approximately 5 days merely for an admission to our specialised unit and a further 9 day delay in obtaining an angiogram. This highlights the intrinsic difficulties that exist in our health care system, and since treatment practice in the management of intracranial aneurysms favours early coiling, sufficient services will have to be put in place before increasing the proportion of patients treated endovascularly for the sustainability of our neuro-interventional unit. Inadequate facilities to undertake angiograms and endovascular treatments increase risk for re-bleeding and thus contribute to mortality. This

was seen in one of the mortality cases where the patient was admitted with a WFNS grade of 1 and deteriorated prior to coiling due to a re-bleed while awaiting coiling. In many instances the delays are due to intrinsic healthcare system issues.

Although it was not an objective sought out by this research it is worth mentioning that an attempt to quantify the duration of coiling procedure and number of coils used was made, however given the poorly kept records we were unable to attain any form of accurate, consistent data in this regard. This information could have assisted in ascertaining a cost profile of the coiling cases. This may become useful as the neuro interventional unit moves forward.

In conclusion the amalgamation of data and subsequent analysis thereof found that more females had aneurysmal coiling than males (58% vs 41%), more black people with a percentage of 62% were treated than other ethnicities and the mean age of patients treated was 46 years. The most common modifiable risk factors were hypertension and smoking. In addition it was found that HIV was also a risk factor in our study population that requires further investigation. With regard to aneurysm location, the anterior circulation territory aneurysms were by far the most common treated. Furthermore the two most significant predictors of mortality was WFNS grade on admission and aneurysmal size. Finally even though rare, the two most common complications encountered during coiling cases were vasospasm and thromboembolic events. Delays in admission and subsequent coiling speak to

wider systemic health care problems. The findings in this cohort as a single centered retrospective review of clinical cases is fairly supported by similar research in this area

Chapter 5- Conclusion and Recommendations

In the acute care after aneurysmal SAH, multidisciplinary collaboration between neurosurgeons, neuroradiologists, neurointensivists and specialist nurses is essential. All incidents of SAH are referred for treatment at intensive care units. Further medical investigations and aneurysm treatments are performed at neurosurgical departments. During the intensive care period, highly advanced technological care is performed, including: continuous observations of neurological functions and vital parameters. After the specific treatments are carried out to secure the aneurysm, effective rehabilitation requires multidisciplinary team competence with experience in stroke care, from physicians, nurses, physiotherapists, occupational therapists, speech therapists and psychologists. During rehabilitation, multidisciplinary interventions follow hospital tailored guidelines and are usually specific and task-oriented, but should also be in accordance with the patient's own goals. This means that the management of aneurysmal subarachnoid haemorrhage patients requires the full spectrum of hospital care that can be provided over a significant amount of time.

Endovascular coil embolization has emerged within the last 2 decades as a safe and effective treatment option

for ruptured intracranial aneurysms (45). Long-term clinical and angiographic follow-up after coiling of ruptured aneurysms confirms its efficacy as a primary treatment technique. Re-bleeding rates after treatment are low, but recanalization remains an issue, even in aneurysms that are initially completely occluded. Long-term imaging follow-up is advised (45).

The neurosurgical and radiological units at CMJAH since 2012 set out to identify and manage intracranial aneurysms via endovascular coiling. Within a short time span it was evident that large number of cases exist. The aim of the research was to evaluate the intracranial aneurysm cases treated by endovascular coiling and to describe and compare these cases with international trends. The significance of the research was that it sought to inform clinical practice in the diagnosis and treatment of intra-cranial aneurysms.

The research found that the number of aneurysm cases treated by endovascular coiling are within the anterior circulation and that most aneurysms are less than 10mm in size with a successful coiling rate of upto 91.94%. The modifiable risk factors such as hypertension and smoking were evident. A significant predictor of mortality was the WFNS grade on admission and aneurysm size. The research also found a significant delay in treatment times which speaks to broader issues within the South African health care system. Overall despite its drawbacks this research has shown that endovascular coiling in its third year of practice at the CMJAH hospital has yielded fair outcomes and the coiling trend in this study mirrors

international work. This means that further implementation by way of training is warranted to keep up with patient demands. In addition this study provides a base upon which further research in this area can be conducted.

Coiling is durable, less invasive and has stood the test of time; it has become the first-line treatment modality for the management of intracranial aneurysms worldwide; we at CMJAH are safely set to chart a similar course.

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Appendix A

World Federation of Neurological Societies (WFNS) grading of subarachnoid haemorrhage

WFNSGrade	GCSScore	Major Focal Deficit
0	Intact aneurysm	Intact Aneurysm
1	15	-
2	13-14	-
3	13-14	+
4	7-12	+/-
5	3-6	+/-

Appendix B

The Modified Rankin scale

Grade	Description
0	No symptoms at all
1	No significant disability despite symptoms: able to carry out all usual activities
2	Slight disability: unable to carry out all previous activities. Able to look after own affairs without assistance
3	Moderate disability: requiring some help, but able to walk without assistance.
4	Moderately severe disability: unable to walk without assistance, and unable to attend to bodily needs without assistance.
5	Severe disability: bedridden, incontinent, and requiring constant nursing care and attention
6	Dead

Appendix C

Table 1
(A) Inclusion and (B) exclusion criteria (April 2002 to March 2007)

(A) Inclusion criteria
Aneurysms unsuitable for endovascular treatment as a result of
Unfavourable neck-aspect ratio of the aneurysm
Anatomical variations in the Circle of Willis
Aberrations of intracranial vasculature
Endovascular obliteration attempted but unsuccessful
Early recurrence/re-bleed within 4 weeks following coiling and treated in acute phase during the same admission
(B) Exclusion criteria
Aneurysms treated surgically because
Unavailability of endovascular interventional service
Patient's preference for surgery
Associated intracranial haematoma warranted evacuation
Difficulty in extra-cranial vascular access for endovascular approach
Incidental/asymptomatic aneurysms
Patients lost to follow-up
Delayed (after 4 weeks) recanalisation of aneurysm/compaction of coils treated surgically on an elective basis