# The Role of Computerised Tomographic Angiograms (CTA) and Lateral Neck Radiographs in Penetrating Neck and Oesophageal Injuries

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# Declaration Page

I, Dr. Ferdinand Musawenkosi Oompie, hereby declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree at this or any other university.

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# I. Literature Review

## 1. Introduction

Penetrating neck injuries (PNI's) are defined as injuries that disrupt the full thickness of the platysma muscle in the neck area[1]. They account for 1 – 3% of all trauma admissions in the majority of tertiary medical institutions globally[2]. Although associated penetrating pharyngo-oesophageal injuries (PPOI's) account for only 0.6 – 6.6% of injuries[2-6], they carry a mortality rate of 15% to 44%[4, 5, 7, 8] with direct association to the delay in time of presentation and final treatment[4, 8-11]. Urgent investigations are crucial if a PPOI is suspected, as a 12 to 24-hour delay substantially increases mortality and morbidity[4, 8-11]. The appropriate radiological investigations for PPOI's remain controversial[6] despite them being integral to the management of PNI's.

## 2. PNI Globally and in South Africa

Penetrating neck injuries are common in most regions of the world[1, 9, 11] and their incidence is rising[12]. In the United States of America (USA), they account for 5-10% of all trauma admissions in multilevel trauma institutions[1]. The percentage of patients admitted with PNI in the trauma department at Groote Schuur Hospital, a level I hospital is slightly lower at 2.16% of all trauma admissions annually[9, 13, 14]. There are however, other countries and regions where PNI's are rare such as Japan[1], the Middle East[15] and parts of Europe[7]. Patients with these types of injuries are predominantly males, with a prevalence ranging from 71%[7] to 98%[16], and most injuries are related to violence[6, 8, 15, 17].

## 3. Penetrating Pharyngo-Oesophageal Injuries (PPOI's)

The cervical oesophagus and pharynx are well protected from injury by their central position in the neck, small surface area, the cartilaginous trachea anteriorly and the vertebral column posteriorly[4, 6, 15, 18]. Thus, despite the high incidence of PNI's[1, 9, 11], associated PPOI's are rare, accounting for 0-14% of PNI's[2-4, 7-10, 13, 15-17 19, 20]. Three previous studies of PNI's at Groote Schuur Hospital found associated rates of associated PPOI's of 4.3%[9] and 8.9%[9], with one study having no reported injuries[13].

Signs and symptoms of PPOI's are usually subtle and non-specific[1, 3, 4, 10, 11, 19]. Patients may present with odynophagia, dysphagia or hoarseness of voice[3, 13]. Thus, it is imperative to have a high index of suspicion for imaging to exclude PPOI's[6, 9, 10, 13, 18].

Clinical signs considered more specific for PPOI's are: haemorrhage in the mouth[3], subcutaneous emphysema saliva draining from the wound[13], blood in the nasogastric tube, haematemesis and subcutaneous emphysema. Radiographic signs include pneumomediastinum on chest radiograph[13] and the presence of prevertebral air on lateral neck radiograph[3, 13, 18].

The indistinct presentation of PPOI's and the complexity of the neck structures has resulted in inconclusive agreement as to most appropriate algorithms for investigation and management of these injuries[6-11].

### 3.1.1. Complications of Pharyngo-oesophageal Injuries

Wounds from PPOI's may cause leakage of acid, pepsin, bile and saliva contaminated with bacteria, from the pharynx and oesophagus into the surrounding loose areolar tissues. This may lead to subsequent suppurative infection causing intense necrotising inflammatory response[4]. Furthermore, complications like mediastinitis, abscess, sepsis and even death can occur[1, 4, 10].

There is agreement amongst most authors that a delay in diagnosis and treatment of pharyngoesophageal injuries leads to significant complications and mortality[1, 3-6, 10, 15, 18], in particular a delay of more than 24 hours[6]. A delay of more than 12 hour increases the risk of prolonged leaks by 43%[4] and furthermore lengthens the stay in hospital[18]. It is thus recommended that PPOI's be treated without delay[3, 11, 15].

### 3.1.2. Other Injuries In PNI

Despite the fact that delayed presentation and management of PPOI's results in high morbidity and mortality, the predominant cause of mortality in PNI's is injury to adjacent structures[11, 15]. Arteries and veins are the most injured structures[3, 7, 11, 13, 15, 17] found in 17% to 37% of PNI's[3, 7, 17] and causing half of the deaths by exsanguination. Other deaths are related to airway compromise, cerebral ischaemia and sepsis from PPOI's [6].

Associated symptoms and signs of vascular injuries are more distinct and are classified into 'hard signs' (e.g. active bleeding, expanding/pulsating hematoma)[1, 11] or thrill[19] and 'soft signs' which are less dependable (e.g. systemic hypotension, shock[10] or haematemesis)[1, 11]. The above signs and symptoms, including signs of airway compromise, obligate immediate surgical intervention[1, 3-6, 10, 11].

The second most common injuries are fractures, occurring in 1 – 25% of PNI injuries[2, 3, 7, 17]. Radiologists are implored to report all fractures and displaced fracture fragments including shrapnel from trajectories, as these have a potential to act as missiles that can lead to complications[10].

### 3.1.3. Neck Zones / Anatomy

Historically the cervical area has been divided into anterior and posterior triangles by the anterior border of the sternocleidomastoid muscle with the anterior triangle further divided into three zones[7]. The classification allows for standard reporting[7] and also prediction of the likelihood of injuries to anatomical structures and to facilitate surgical planning[9]:

- Zone I extends from the sternal notch, superior borders of the clavicles inferiorly to a transverse line across the cricoid cartilage superiorly. Its vascular contents are the brachiocephalic arteries and veins, carotid and vertebral arteries. Other structures are the thyroid gland, trachea, oesophagus, thoracic duct and lung apices. Injury to this zone may involve thoracic inlet structures[9].

- Zone II continues from the cricoid cartilage inferiorly to the level of the mandibular angle superiorly. Its vascular contents are the common, external and internal carotid arteries, internal and external jugular veins. Other structures include the oesophagus and pharynx. This is the most commonly injured zone and fortunately the most surgically accessible[7].

- Zone III extends from the angle of the mandible to the base of the skull. Its vascular contents are the vertebral artery, jugular veins, common, internal and external carotid arteries. This zone is the most inaccessible due to surrounding restricting osseous structure like the mandible. Imaging in in this area is pivotal in planning management of these patients[7].

Classifying injuries into zones is problematic as the site of the injury does not always accurately predict the direction of the injury tract or orientation of the trajectory which may involve a different zone[20]. Thus, there is no consensus on a zone-based management algorithm at present[20].

## 4. Mechanisms of injury

Penetrating neck injuries can be classified as low-velocity or high-velocity injuries. Low velocity injuries are caused by knives or other sharp objects and low-velocity handguns. High-velocity injuries are caused by high calibre rifles and result in much more significant injury[3, 6, 9]. The trajectory of bullets from firearms effect harm as it imparts its kinetic energy through shock waves within the tissues, causing thermal injury and further dispersion of shrapnel. This results in unpredictable injuries often requiring surgical exploration. In general, the approach to high velocity and low velocity injuries is similar[3, 6].

Globally the majority of PNI's and are caused by stab wounds accounting for 52% to 89% of the injuries[6, 8, 17] followed by firearms which cause 11% to 47% of the PNI's[8,

[9, 17]. There are however exceptions, for example in parts of the USA where the most used weapons are firearms[2] and in Saudi Arabia where the main cause of PNI's is road traffic accidents (53%)[15]. In Japan, PNI's are rare and the few encountered cases are caused by self-harm and road traffic accidents[1] instead of violence.

## 5. Violence in South Africa

South Africa has a high level of violence[21, 22] which places a burden on the health services. Annual murder rates which are internationally used to estimate and compare levels of violence among different countries were 60 per 100 000 in the 1990's and declined to 39 per 100 000 in 1994 after the first democratic elections were held. South Africa is however not unique as violence affects most countries where the majority of the citizens are from a low socio-economic background[21, 23]. There are only a handful of countries with similar statistics found in the Caribbean and South America. In 2004, the murder rate in Columbia was 46 per 100 000[21].

Comparison with neighbouring African countries is difficult as some countries do not diligently record levels of crime or murder[21]. A survey analysing non-fatal violence among 17 African countries rated South Africa fifth in responses to experience of assault by the general population in the years 2004 to 2006[21]. Injury rates are just as high, recently quoted at 158 per 100 000[22], also causing significant morbidity.

The most recent South African Burden of Disease Data indicates that interpersonal violence and road traffic accidents are the main causes of Years of Life Lost[22]. Additionally, the latter two are part of the identified quadruple burden of disease to be targeted by the new proposed National Health Insurance[22], which includes HIV/AIDS and tuberculosis, maternal neonatal and child morbidity and mortality, and non-communicable diseases[22].

## 6. Pre-operative Investigation of PNI's

As discussed previously, the clinical presentation of PPOI's, in particular oesophageal injuries, are non-specific making preoperative diagnoses much more crucial[5]. It is imperative that patients with life-threatening injuries are immediately taken for surgical exploration which usually excludes them from most preliminary radiological investigations[2, 3, 6-8, 11, 13, 15, 17, 19, 20].Various pre-operative investigations can be performed, with practice varying between institutions. These include lateral soft-tissue neck radiographs, colour Doppler and duplex ultrasound, chest radiographs, digital subtraction angiograms (DSA), Multidetector Computerized Tomography Angiography (MDCTA), endoscopy, contrast swallow and magnetic resonance imaging (MRI).

### 6.1.1. Lateral Soft Tissue Neck Radiographs

Generally the first preoperative radiological investigation, it is cost effective and readily available[24, 25]. Presence of prevertebral air in conjunction with clinical signs such as odynophagia is suggestive of a PPOI[4, 6, 13, 18]. It may however be underutilised but with proper training, emergency physicians can use it to its fullest potential[25].

### 6.1.2. Multidetector Computerized Tomographic Angiography (MDCTA)

The use of this imaging modality for neck injuries has been gaining favour[9] since its introduction in 1998[26] and is now an integral part in most emergency and trauma centres worldwide[9]. It has demonstrated high sensitivity of 90% to 100%, specificity of 92.8% to 100%[9, 19, 27], positive predictive value of 92.8% to 100%[27] and negative predictive value of 98% to 100%[27] in analysing vascular injuries. There has been no study comparing sensitivity and specificity of MDCT versus contrast swallow in detecting POI's.

Oesophageal injury on MDCTA may appear as thickening of the oesophageal wall, peri-oesophageal gas loculation, fluid collection, mediastinal fluid collection,

posterior mediastinal inflammation or more directly as a focal oesophageal wall defect[1].

MDCTA is widely available and does not require the support of additional nonphysician staff[7]. The patient does not have to be secluded in a sterile field as in a DSA investigation discussed below, thus allowing easier access and close monitoring[19]. There is rapid imaging data acquisition and post-processing which minimizes the time spent by the patient in the radiology department away from the point of care unit[28]. Contrast is administered via a peripheral line with no need for central arterial puncture and access. There is generally lower radiation exposure to the patient and the radiology department staff compared to DSA[19].

Further, CTA offers clearer high-resolution visualization of the aerodigestive tracts, thyroid gland, trachea, lungs, other surrounding soft tissue viscera and osseous structures of the cervical spine[9]. Determination of the wound tract or direction of the bullet trajectory, location of shrapnel and fracture fragments assists in evaluation of injuries or potential damage to surrounding and adjacent structures[1, 9, 10] in particular the pharyngoesophageal area. It is sensitive for aerodigestive injuries however its specificity remains questionable[19].

MDCTA has shortcomings which include susceptibility to artefacts from high density material or metallic structures (e.g. orthopaedic hardware) and high-density anatomical structures (e.g. shoulders)[9]. Some studies found a false positive rate of 10.3%[19] to 13%[17] and also claimed that using close proximity of the injury tract in MDCTA to assess vascular or visceral injuries had a low yield[17].

MDCTA has mostly replaced DSA for arterial injury evaluation[1, 7, 9], decreasing the number of negative neck explorations and contrast swallow studies[11].

### 6.1.3. Digital Subtraction Angiography (DSA)

Although this procedure is not used often[1, 7, 9], it is still viewed as the 'gold standard' for diagnosing vascular injuries in PNI's [7, 9]. It is mainly used in cases where MDCTA results are equivocal[9, 10] and in vascular injuries where intervention is required e.g. embolization of pseudoaneurysm[9].

It has numerous disadvantages, which include the fact that it is labour intensive[9] and is associated with more complications compared to MDCTA[9]. Thus, it has mostly been replaced by MDCTA in diagnosing vascular injuries[1, 7, 9].

### 6.1.4. Iodine containing contrast media

Iodine containing contrast media is used in both DSA and MDCTA investigations. This carries risks of contrast induced nephropathy and severe allergic/anaphylactic reaction [29]. Although these adverse events are minimal, accounting for 0.2% to 0.7% of all studies[29], radiologists and physicians have to create awareness and take necessary precautions.

### 6.1.5. Contrast swallow

Also known as oesophagogram or barium swallow. This has evolved from being historically used to assess swallowing mechanism, pharyngeal and oesophageal anatomy in the beginning early 20th century to its present status of being able to also investigate oesophageal tumours and PPOI's[30]. It is an inexpensive, non-invasive procedure able to record live fluoroscopic cine imaging, ideal in identifying pharyngo-oesophageal disruption and tracking traumatic fistulae related to PPOI's[30].

The recommended procedure protocol to identify PPOI's in a trauma setting is a biphasic procedure, where initially iodine-based water-soluble contrast is swallowed by the patient with intermittent fluoroscopic imaging. This is then followed by diluted barium sulphate suspension when the latter initial step is normal, so as to exclude smaller pharyngo-oesophageal defects that can be initially missed[10].

It has a sensitivity of 48 – 100%, a false negative rate of 10 – 20%[4], a specificity of 96%[3] and is still viewed as the 'gold standard' for diagnosis of PPOI's[5]. It is however time consuming, requires presence of a radiologist to perform the procedure and the patient has to proffer full co-operation, which is not always possible in emergency situations[10].

### 6.1.6. Colour Doppler and Duplex Ultrasound

This modality is mainly used to exclude vascular injuries, particularly in Zone II and Zone III neck regions[31]. It is a non-invasive, widely available, fast and non-radiation emitting preoperative imaging device[31]. It has shown a sensitivity of 95–100%[23, 31], specificity of 95–98% and accuracy of 98%[23] in vascular injuries. There are however some draw-backs related to ultrasound; like artefact from shrapnel and surgical emphysema[23]. Ultrasound cannot be confidently used to diagnose PPOI's due to gas and air interference[23, 31].

### 6.1.7. Magnetic Resonance Angiography (MRI)

This form of imaging has been constantly advancing since the first human in vivo anatomical image of a finger in 1977[32]. The main use in PNI's are to exclude vascular injuries, neurological injuries of the cord and peripheral nerves. Its use is however limited due to artefacts from shrapnel, time-consuming sequences, restricted MRI compatible emergency medical equipment and lack of accessibility related to expense[9].

### 6.1.8. Oesophagoscopy or Panendoscopy

Rigid and flexible endoscopes are used to directly visualize injuries of the pharynx and the oesophagus. Rigid endoscopy is preferred for the post-cricoid pharynx and upper oesophagus as it does not require air insufflation[33]. Endoscopes have an advantage of being easily accessible by treating physicians and are invaluable for patients not suitable for contrast swallow e.g. unconscious patients. Together with contrast swallow they provide a sensitivity of 90% - 100% in diagnosing PPOI's[10].

# 7. Management Of Penetrating Neck Injuries

There has been continuous controversy with regards to management approach to PNI's and PPOI's[4, 6, 9-11]. Most articles on PNI's predominantly focus on management and its progressive innovation throughout the decades.

### 7.1.1. History of PNI Management

In the early 20th century, non-operative management of non-critical neck injuries was the prevailing practice. This changed in 1956 after a study suggested that mandatory exploration of the neck in PNI resulted in less mortality and morbidity than the observation approach, which continued to the early 1980's[11]. Subsequent studies in this period criticized mandatory surgical exploration for its high costs and high negative rate of exploration[3, 6, 13, 19, 20], quoted as between 25%[13] and as high as 89%[8], with a morbidity of 50%[13]. Additionally, most of the described injuries were non-critical, self-resolving venous and pharyngo-oesophageal injuries[11].

There were also multiple studies in the same period of the 1980's which proposed that patients with non-critical PNI's, not requiring immediate surgical exploration could be observed. This approach gained momentum throughout the 1990's up to the present day[1, 3, 4, 7-11, 13, 15, 17].

### 7.1.2. Selective Non-Operative Management (SNOM)

The general consensus of the studies in the 1990's led to a new approach which is based on careful clinical examination[3, 6-8, 10, 13, 15, 17, 19, 20], that then guides the next necessary steps of investigations prior to final management. Patients are first generally classified into a three-tier triage which forms the diagnostic management algorithm viz[19]:

1. Unstable patients with the previously described 'hard signs' are taken for immediate exploration without further investigations[3-6, 10, 11].

2. Patients with no sign of injury are observed[2-4, 7, 13, 19]and kept nil per mouth with nasogastric feeds[4, 17] for 24 hours[19 3], 48 hours[6, 11, 13, 17] or up to 72 hours [13].

3. The rest of the patients with 'soft signs' are then further investigated using the various described pre-operative investigations which include radiological investigation at the discretion of the attending surgeon[6, 11, 13, 17](see section 6).

On contrast swallow investigation, PPOI's can also be further classified in order to guide final management. Large leaks to surrounding tissue or into the mediastinum are immediately repaired and small blind ending leaks - also seen on panendoscopy - are treated conservatively[6, 34]. Conservative management has been shown to have up to 80% spontaneous healing with only 20% of patients developing localised abscesses and 6% developing local complications[4].

The conservative approach has been criticized for its high costs of investigations and low yield of results[8]. Some studies also criticized the process of using proximity of the injury tract to assess vascular and visceral injuries on MDCTA as providing low yield results[17]. Multiple diagnostic procedures in particular MDCTA's, also have a potential to lead to 'clinical laziness' which may subvert actual physical examination described as the 'cornerstone' of SNOM[17].

The main drawback of preoperative investigations has been the associated delay between admission and final management with resultant increase in morbidity and mortality[7, 15, 18]. A recent study of penetrating oesophageal injuries at Groote Schuur demonstrated an overall delay from injury to final management with a mean of 36 and half hours and a median of 15 hours resulting in complications[18]. A similar study in the USA in 2001, investigating delays caused by pre-operative investigations found a mean interval of 13 hours[5, 18]. However, a follow up study in 2014, found significant improvement in the delay with a mean of only one hour[5]. This vast improvement in efficiency was attributed to increased awareness after the earlier study[5].

## 8. Conclusion

Most PNI's are caused by violent crime which is prevalent in South Africa. Although associated PPOI's are rare, their complications result in significant morbidity and mortality. Delay in final management has been identified as an important factor in worsening of PPOI's complications.

The focus of most studies of PNI's and PPOI's are on management and investigations, which despite being in evolution for the past four decades have remained controversial.

Throughout all the innovations, clinical examination and preoperative investigations, in particular MDCTA, have emerged as the main guide in planning final treatment and intervention. Selective non-operative management is practiced on patients with no suspected life-threatening injuries and with soft signs and symptoms suggestive of internal cervical injuries and PPOI's. Patients with associated life-threatening injuries are immediately taken to theatre for exploration and patients not suspected of internal neck structures injuries are observed. Thus, both groups are excluded from further investigations.

Lateral soft tissue neck radiographs and MDCTA's have a role to play in diagnosing PPOI's in patients with PNI's, however contrast swallow, which is time consuming, is still viewed as the 'gold standard'. MDCTA is utilized mainly to diagnose vascular injuries but has shown high sensitivity in diagnosing PPOI's although its specificity is still questionable.

Preoperative investigations do increase the delay in final treatment. Optimizing efficiency in preoperative investigations is crucial in preventing delays which lead to the described complications.

# II. Full Text Journal Article For Submission

## 1. Cover Letter

**Full Title:**

***The Role of Computerised Tomographic Angiograms and Lateral Neck Radiographs in Penetrating Neck Oesophageal Injuries.***


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- Assisted in editing the portfolio and research
- Assisted in data collection and analysis
- Drawing of graphs in data analysis
- Liaison with research departments and general administration.

**Prof Andrew Nicol – Co-supervisor:**

- Initial set-up of research and proposal
- Advise and provision of patient data
- Provision of literature

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**Tables:**

**Table 1**: Summary of POI Findings from All Modalities.

**Table 2:** Two Way Summary Table of Prevertebral Air Findings Compared to Contrast Swallow.

**Table 3:** Two Way Summary Table of MDCTA Findings Compared to Contrast Swallow.

**Charts:**

**Chart 1:** Contrast Swallow findings of POI.

**Chart 2:** Comparison of Findings of Prevertebral Air and Contrast Swallow (labelled as 'POI').

**Chart 3:** Comparison of Findings of MDCTA and Contrast Swallow.

**Figures:**

**Figure 1:** 28-year old male with a stab wound left zone III and bleeding on the scene. Suspected to have POI.

**Figure 2:** 20-year-old male with stab wound left zone II. Suspected of POI.

**Figure 3:** 20-year-old male with a stab wound in left zone I, bleeding at the scene and Foley's catheter inserted at the wound site for homeostasis.

**Title:** The Role of Computerised Tomographic Angiograms and Lateral Neck Radiographs in Penetrating Neck Oesophageal Injuries.

# 2. Abstract


**Background**

South Africa has a high rate of injuries related to violence which includes penetrating neck injuries (PNI's). Of the 163 patients that are annually referred for contrast swallow studies to exclude associated pharyngo-oesophageal injuries (PPOI's), only 0-14% contrast studies confirm injury.

The contrast swallow is still viewed as the 'gold standard' for oesophageal pathology even in the modern era of digital general radiography and Multidetector Computerized Tomographic Angiogram (MDCTA). This procedure is however time consuming and requires good cooperation, sometimes from acutely ill patients which is not always possible. This contributes to delay in final management of the patient which is the most significant contributor to associated complications.

The study reviewed whether the less time-consuming MDCTA's and lateral soft tissue radiographs usually performed before the contrast swallow studies can also be used to diagnose POI's. This will reduce dependence and possibly exclude the contrast swallow study, thus reducing the time delay in POI pre-operative investigations.

**Methods**

A retrospective review was undertaken of the radiological findings of all patients who presented at Groote Schuur Hospital over a 28-month period with suspected penetrating neck injuries and were investigated with a contrast swallow, MDCTA and lateral soft tissue radiograph.

The time interval between request of the contrast swallow study and the final report was calculated as the difference in the time indicated on the Groote Schuur Hospital Philips Extended Internet Radiology Information System (XIRIS) by the requesting clinician and the time indicated on the radiology report after completion of the study on the Philips Picture Archiving and Communicating System (PACS).

**Results**

Of the 389 patients referred, 153 patients met the study criteria. Fourteen patients (9%) had PPOI's on contrast swallow. The majority of the patients with PPOI's had prevertebral air (12; sensitivity of 85.7%), however a majority of patients with prevertebral air had no POI's (90; specificity of 35.3%). In 28 MDCTA's where there was suspicion of PPOI's, six contrast swallows confirmed oesophageal leaks (42.9% sensitivity). Although there was no suspicion of PPOI'S in 125 patients undergoing MDCTA's, eight were found to be positive for leaks on contrast swallow (84.2% specificity). The mean time interval between request of the contrast swallow study and final report was 586 minutes.

**Conclusion**

Contrast swallow remains the gold 'standard' for diagnosing PPOI's in patients with PNI's. The lateral soft tissue radiograph was unreliable in predicting POI's with a low specificity of 35%. MDCTA's was also not contributory in assisting diagnoses of PPOI's with a low sensitivity of 43%. The two modalities can thus not be considered as augmentation or alternative diagnostic modalities. The time delay between the request and reporting of the contrast swallow is longer than that in literature and needs improvement.

# 3. Introduction

Penetrating neck injuries (PNI's) are defined as injuries that disrupt the full thickness of the platysma muscle of the neck[1]. They account for 1 – 3% of all trauma admissions in the majority of tertiary medical institutions globally[2, 4]. Although associated oesophageal injuries occur in only 0.6 – 6.6% of PNI's[2-6, 8], they carry a 15 to 44% mortality rate[4, 5, 7, 8]. This is closely associated with the delay in time of presentation to initiation of definitive treatment. Therefore, expediting preliminary investigations is crucial if a POI is suspected, as a 12 to 24-hour delay substantially increases mortality and morbidity[1, 3, 4, 6, 11, 18].

Worldwide, most PNI's are related to violent crime with the commonest mechanism of injury being stab wounds followed by gunshot wounds[1, 2, 18]. This is comparable to our institution (Groote Schuur Hospital in Cape Town, South Africa), where recent studies by Thoma et al and Scholtz et al demonstrated that over 200 patients were admitted annually with PNI's also caused mostly by stab wounds followed by gunshot wounds [3, 9].

Despite recent advancements in imaging technology and introduction of the MDCT in 1998[26], the contrast swallow is still viewed as a 'gold standard' for imaging oesophageal pathology[5] despite its introduction in the early 20th century[30]. There is still however controversy with regards to appropriate investigations for PPOI's[7-9].

This study analysed whether complementary imaging investigations including MDCTA's and lateral neck radiographs could augment the diagnosis of PPOI's so as to expedite preoperative investigations. We analysed MDCTA's which were performed to exclude vascular injury and in conjunction with clinical findings are conventionally used to guide management of PNI[7, 9, 10]. Additionally, we analysed lateral soft tissue radiographs performed to exclude surgical emphysema which is suggestive of a

cervical viscous perforation indicating presence of a PPOI[4, 13, 24] and compared to the gold standard investigation of a contrast swallow.

# 4. Research Methods and Study Design

### 4.1.1. Study design

Retrospective review of patient folders and radiology reports.

### 4.1.2. Aims

**Primary aim:**

- To determine the sensitivity and specificity of MDCTA's and lateral soft tissue radiographs in assisting with the diagnosis of PPOI's in PNI's by comparing them to the contrast swallow.

**Secondary aims:**

- To evaluate the time interval between request for contrast swallow studies and finalization of the report at Groote Schuur Hospital.
- To describe the demographics of the patient with penetrating neck injuries as well as the mechanism of injury.

### 4.1.3. Inclusion and Exclusion Criteria

All patients who presented to the trauma department at Groote Schuur Hospital, a tertiary academic hospital in the Western Cape Province of South Africa, with suspected PNI and were investigated with contrast swallow, MDCTA and a lateral soft tissue radiograph from 1st March 2014 to 31st July 2016. Patients were excluded if they had injuries attributable to iatrogenic causes, recent pharyngo-oesophageal surgery, suboptimal or inaccessible radiological studies. The indication for the radiological investigations were at the discretion of the treating physician.

### 4.1.4. Methods and Data collection

Patients were identified by searching for specific phrases in the contrast swallow, MDCTA's and lateral soft tissue studies radiology reports on the Groote Schuur

Hospital Philips PACS, which included: ‘pharyngeal injury’, ‘oesophageal injury’, ‘penetrating’, ‘barium swallow’, ‘contrast swallow’, and ‘neck’. Data was recorded in Microsoft Excel where a number cypher was used to protect patient confidentiality.

Presence or absence of POI’s were obtained from the contrast swallow reports, viewed as the ‘gold standard’ in literature and also for the purpose of this study. Results were recorded under the heading ‘positive’ or ‘negative’ respectively. Further information from the clinical history in the reports were also recorded for clinical. This includes age, gender, mechanism of injury labelled as: ‘ stab wound’, ‘gun-shot wound’ or ‘not specified’, side of injury: ‘left’, ‘right’ or ‘not specified’, site of injury: ‘zone I’, ‘zone II’, ‘zone III’, ‘posterior triangle’ or ‘site not specified’. Lateral soft tissue radiographs reports, findings were also recorded under the headings ‘presence of prevertebral air’ and ‘absence or prevertebral air’.

Reports of POI’s on MDCTA’s were also obtained from the radiology reports and recorded under the headings: ‘no suspicion of POI’, where POI was excluded or probability of its presence or absence was not indicated. For the purpose of this study, this was viewed as negative for POI. Where POI was suspected, the heading ‘suspicion of POI’s’ was used and viewed as positive. Further injuries were also tabulated for clinical interest as indicated, under the headings: ‘vascular injuries’ and ‘osseous injuries’ for various fractures.

The time interval between requests of the contrast swallow and final report was calculated as the difference in time period between the electronically logged request on the Groote Schuur Hospital Philips XIRIS Internet Radiology Information system by the requesting clinician and the time indicated on the radiology report after completion of the study on the Philips PACS.

### 4.1.5. Data analysis

All data was captured in an Excel spreadsheet and exported to STATISTICA 13.5 for statistical analysis. The McNemar test was used to compare the nominal dichotomous outcomes of the new tests with the same outcomes due to the gold standard. The subsequent contingency table was used to calculate the sensitivity and specificity as well as the positive (PPV) and the negative predictive values (NPV) of the investigated tests versus the gold standard. Non-parametric data was expressed in medians and confidence intervals (CI). A p-value of less than the significance level alpha <0.05, was considered statistically significant.

### 4.1.6. Ethical considerations

Ethical approval was granted by the Human Research Ethics Committee of the University of Cape Town. HREC Ref 795/2017.

## 5. Results

The study was carried out over 28 months. Of the 389 patients referred with PNI's for contrast swallow, 153 had the required additional adjunct imaging i.e. MDCTA's and lateral radiographs as part of their imaging investigations. The mean age was 28.8 ± 8.7 years and 146 (94.4%) patients were males. There were 117 (76.5%) stab wounds and 36 (23.5%) gunshot wounds.

| | | **Positive for POI on Contrast Swallow** | **Negative POI on Contrast Swallow** |
|---|---|---|---|
| **Cohort** | **153** | 14 (9.1%) | 139 (90.8%) |
| Presence of prevertebral air on lateral radiograph | 102 (66.6%) | 12 (11.7%) | 90 (88.2%) |
| No prevertebral air on lateral radiograph | 51 (33.3%) | 2 (3.9%) | 49 (96.1%) |
| MDCTA: suspicion of POI | 28 (18.3%) | 6 (21.4%) | 22 (78.6%) |
| MDCTA: No suspicion of POI | 125 (81.7%) | 8 (6.4%) | 117 (93.6%) |

**Table 1. Summary of POI Findings From All Modalities**

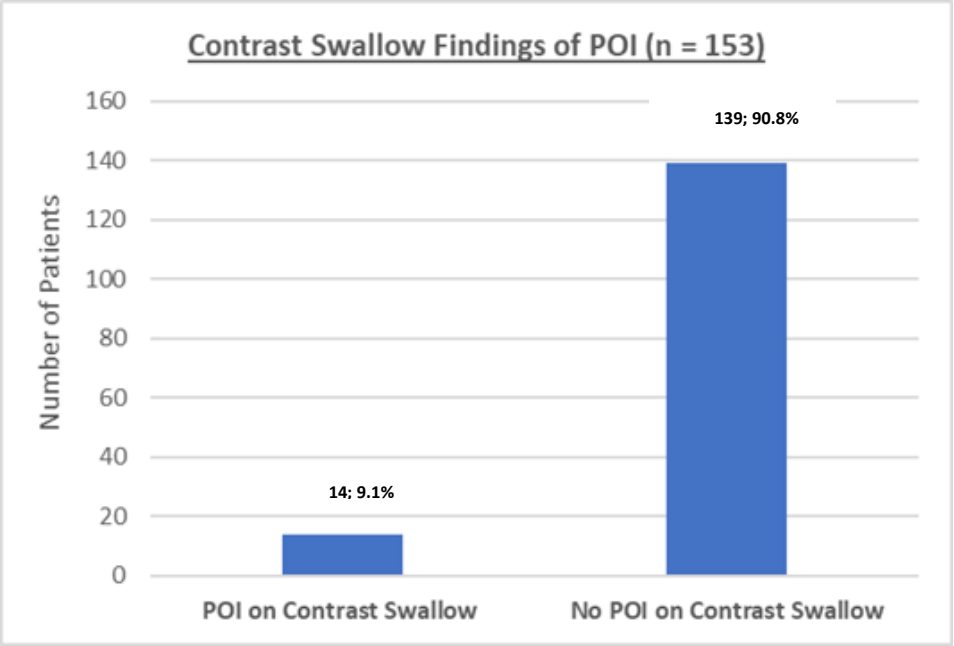


**Chart 1. Contrast Swallow findings of Penetrating Oesophageal Injury (POI)**

The contrast swallow series confirmed 14 (9.1%) cases with PPOI's, 11 stab wounds and three gunshot wounds, which accounted for 9.4% of the total stab wounds and 8.3% of all gunshots. (table 1 and chart 1).

| | 2 Way Summary Table: Observed Frequencies | | |
|---|---|---|---|
| **Prevertebral Air** | **Contrast Swallow** Positive | **Contrast Swallow** Negative | Row Totals |
| Positive | 12 (11.8%) | 90 (88.2%) | 102 |
| Negative | 3.9 (2.0%) | 49 (96.1%) | 51 |
| **Totals** | 14 | 139 | **153** |

**Table 2. Two Way Summary Table of Prevertebral Air Findings Compared to Contrast Swallow**

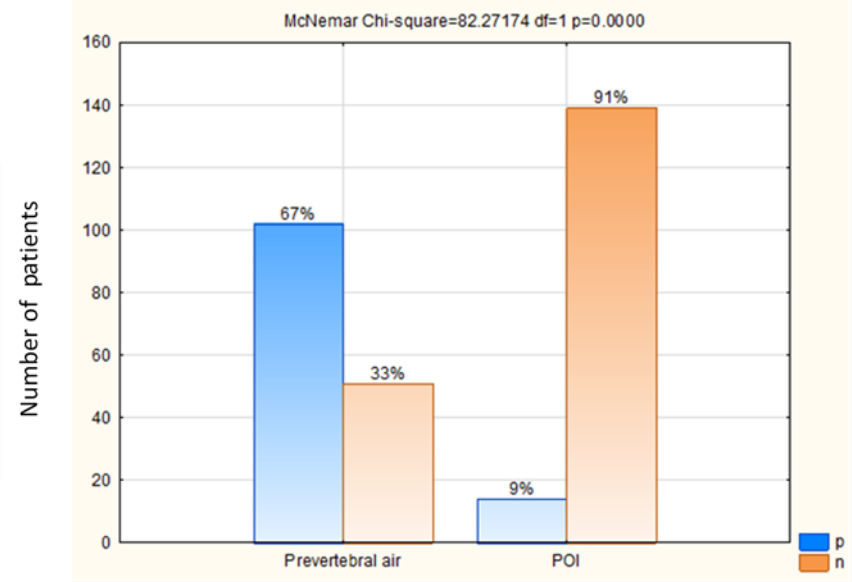


**Chart 2. Comparison of Findings of Prevertebral Air and Contrast Swallow (POI) (p=positive; n=negative)**

Lateral soft tissue radiographs demonstrated prevertebral air in 102 (66.6%) patients. The discordance of sensitivity between prevertebral air on lateral neck was significant (Chi-square McNemar p <0.001). There were 12 true positive, 90 false positive, two false negative and 49 true negative studies compared to contrast swallows (see table 2 and chart 2). The positive predictive value was 0.118 and the NPV was 0.961 with a sensitivity of 85.7%, 95% [CI 0.781, 0.902] and a specificity of 35.3%, 95% [CI 0.273, 0.432]. The likelihood ratio of a positive test (LR +ve) of 1.324 and likelihood ratio of a negative test (LR -ve) of 0.405.

| | 2 Way Summary Table: Observed Frequencies | | |
|---|---|---|---|
| **MDCTA** | **Contrast Swallow** Positive | **Contrast Swallow** Negative | Row Totals |
| positive | 6 (21.4%) | 22 (78.6%) | 28 |
| Negative | 8 (6.4%) | 117 (93.6%) | 125 |
| **Totals** | 14 | 139 | **153** |

**Table 3. Two Way Summary Table of MDCTA Findings Compared to Contrast Swallow**

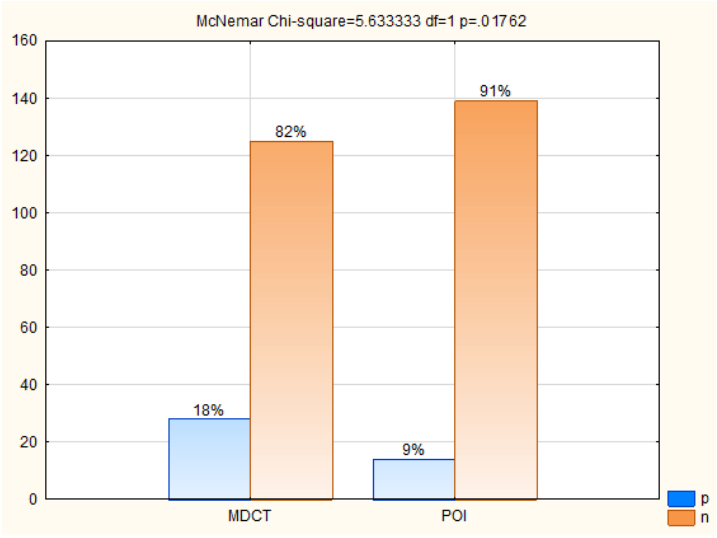


**Chart 3. Comparison of Findings of Multidetector Computer Tomogram (MDCTA) and Contrast Swallow (POI). (p=positive; n=negative)**

The likelihood of PPOI'S was not mentioned in 125 (87.7%) of the MDCTA's and for the purpose of this study this is presumed to be negative for POI's. The discordance of sensitivity between prevertebral air on lateral neck was significant (Chi-square McNemar p <0.05). There were 6 true positive, 22 false positive, 8 false negative and 117 true negative studies compared to contrast swallows. (see table 3 and chart 3). The PPV value was 0.214 and the NPV value was 0.963 with a sensitivity of 42.9%, 95% CI [0.169, 0.688] and a specificity of 84.2%, 95% CI [0.781, 0.902]. The likelihood ratio of a positive test of 2708 and likelihood ratio of a negative test (LR -ve) of 0.679.

Injuries were predominantly left-sided, (n=76; 48.4%), of which 64 (54.7%) were stab wounds and 12 (33.3%) gunshot wounds. Forty-three (28%) Injuries were right sided with 28 (23.4% ) of them caused by stab wounds and 16 (44%) due to gunshots. The side of injury was not mentioned in 31 (20.3%) of the patients. The anatomical zonal distribution of injuries was predominantly in zone II with 89 (58.2%) injuries, followed by zone I with 27 (17.6%) injuries and zone III with 10 (6.5%) injuries.

The commonest injured structures were vessels, reported in 50 (32.7%) of the MDCTA's. Seventeen were internal jugular vein injuries (11%), common carotid artery and vertebral arteries were both 7 (4.6%) respectively. Osseous injuries included 15 clavicle fractures (9.8%), four rib and mandible fractures respectively (2.6%).

Time delay between the request of the contrast swallow to the radiology report was a mean of 586 minutes.

## 6. Discussion

Diagnosing and managing POI's remains a challenge for trauma surgeons and radiologists as most PNI's are not associated with POI's[8]**.** The latest technology in radiology which includes MDCT and digital imaging radiography has not been adequately explored to assist in diagnosing POI's with continued reliance on the time-consuming contrast swallow[10].

In an interval of 28 months, 389 patients with PNI's suspected of PPOI's were referred for contrast swallow from our trauma departments. This equates to a mean of 163 patients per annum, similar to two previous studies in our institution by Thoma et al and Scholtz et al, who despite slightly different time intervals, both co-incidentally had 203 patients[3, 9]. Our cohort size of 153 was slightly smaller as 236 patients were excluded because they did not have all the required complimentary imaging studies of a MDCTA and lateral soft tissue radiograph.

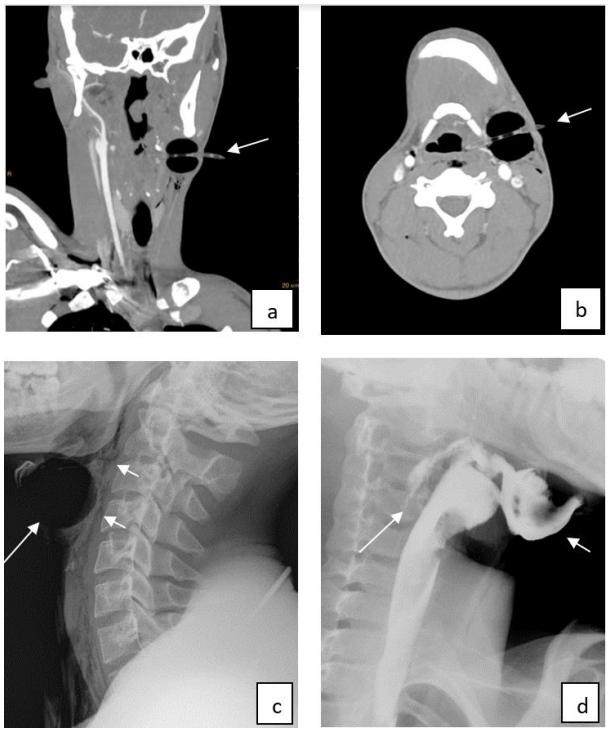


**Figure 1 (a-d): 28-year old male with a stab wound left zone III and bleeding on the scene. Suspected to have PPOI. (a) and (b) Coronal and axial reformatted contrasted MDCTA: Foley's catheter in the left neck (arrows) inserted for homeostasis. (c) Lateral neck radiograph: significant neck surgical emphysema extending to the prevertebral area (short arrows). The round low-density structure is the Foley's catheter balloon (long arrow). (d) Water-soluble contrast swallow oblique view: large penetrating pharyngeal injury with tracts in the left hypopharynx (short arrow) and retropharyngeal region (long arrow), confirming PPOI.**

This high incidence of penetrating neck injuries in this cohort(169.1p.a) is typical of the violent crime rate in South Africa[22, 35]. Although this statistic has often been attributed to socioeconomic status, this has not been reflected in the literature with significantly lower rates of PNI's being reported in Brazil(32.2 p.a.) [12] and India (7.0 p.a.)[36]. However, despite this, the incidence of confirmed positive PPOI's (n=14, 9.0%) on contrast swallow was similar to the range in the literature of 0-14% annually[2-4, 7-9, 13, 15, 17]. This suggest that the ratio of positive PPOI's per contrast image referral is independent to that of the burden of disease.

A significant number of the patients had prevertebral air (n=102, 66.7%), which included 12 true positive findings for PPOI's (fig. 1) and only two false negative findings (fig. 3), giving a high sensitivity of 85.7%. The specificity was however low (35.4%), as most patients with prevertebral air had no POI (low LR -ve of 0.405) (fig. 2). Although one cannot discount the screening value where there is an index of suspicious, it is clear that the presence of prevertebral air on a lateral neck radiograph

cannot replace contrast swallow for POI diagnosis, as the latter has high sensitivity of up to 100% and a specificity of 96%[3].

Furthermore, MDCTA's had inferior diagnostic accuracy compared to the contrast swallow, however the relationship between sensitivity (42.9%) and specificity (84.2%) was reversed, with an LR -ve of 0.679. Although this result may be anticipated by clinicians, the lack of objective data in the literature makes this finding relevant.

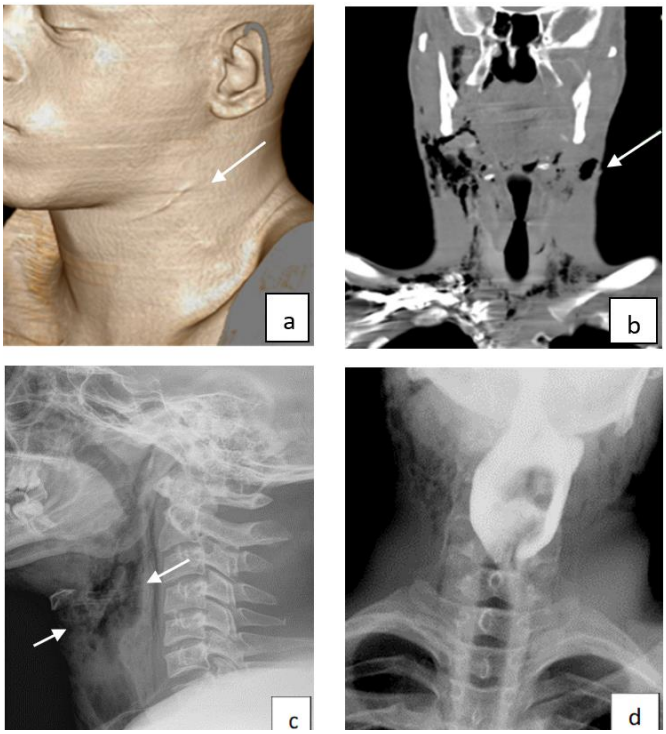


**Figure 2 (a-d): 20-year-old male with stab wound left zone II. Suspected of PPOI. (a) MDCTA 3D reformatted image demonstrates the wound site (arrow). (b) MDCTA coronal reformatted: wound tract in left zone III (arrow) with significant cervical surgical emphysema. There was no vascular injury. Fig (c) lateral soft tissue lateral radiograph: significant prevertebral air and cervical surgical emphysema (arrows). (d) Frontal view water-soluble contrast swallow; a PPOI was excluded.**

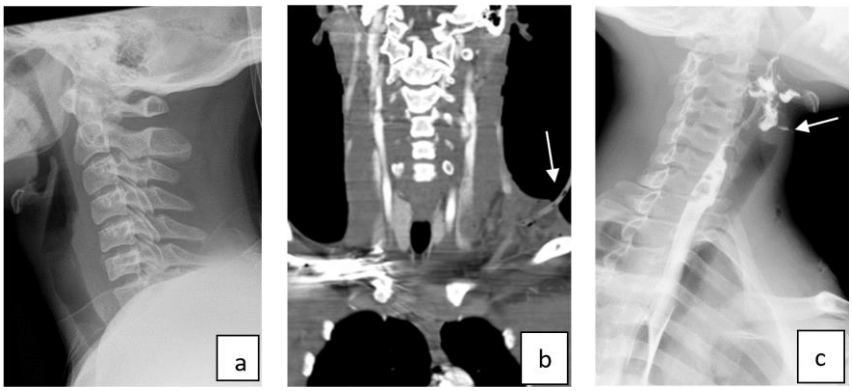


**Figure 3 (a-c): 20-year-old male with a stab wound in left zone I, bleeding at the scene and Foley's catheter inserted at the wound site for homeostasis. PPOI was not suspected on MDCTA. (a) Lateral soft tissue radiograph of the neck with no prevertebral air evident. (b) MDCTA coronal reformatted shows Foley's catheter in situ in the left lateral neck zone I (arrow). There was no large vessel injury. (c) Oblique view water-soluble contrast swallow demonstrates a small contained leak in the left pyriform sinus (arrow), distant from entrance wound. Even though no prevertebral air visible.**

The mean time interval between the request of the contrast swallow and final report was 586 minutes. This adds to the overall time delay to final treatment, in particular for patients who may require surgical management. Although the causes of the delay and whether there were associated complications were not explored in this study, this can be improved with increased awareness[5] to prevent the described associated complications[1, 3, 4, 6, 9, 18]. Furthermore, we do not recommend the routine use of MDCT for aerodigestive diagnosis in a resource limited setting. Delays in access to scanners are inherent in this environment and add little diagnostic value to this cohort.

The majority of our patient cohort were male (n=146; 94.4%), which is similar to the global reports of 71% to 91.8%[2-4, 7-9, 13, 15-18], as most violence is predominantly perpetrated by males on males. The mean patient age was 27.8 ± 8years, which corresponds with international findings and is reflection of the age of patient involved in violent crime [2-4, 8-10, 13, 16-18], although older age groups have also been reported in the US and Saudi Arabia, with a mean age of 33.8 (4-92) and 31 (16 – 68) respectively[7, 15].

The majority of the injuries were caused by stab wounds (n=117, 76.5%) with the remainder being gunshot wounds (n=36, 23.5%), as has been reported previously in the international literature[7, 8, 12, 36] and previous studies from Groote Schuur Hospital[9, 17]. The bulk of the injuries were in zone II (58.2%) followed by zone I (17.6%), as has been reported previously[7, 9, 10]. Since zone II is the largest and most exposed zone, it is more likely to be injured[10] and fortunately, it is also the most surgically accessible[7].

Furthermore, most injuries occurred on the left side of the neck, found in 76 (50%) patients compared to the right side 43(28%), the remainder were undocumented. Of the stab wounds 64 (55%) were left sided, more than double to those on the right 28 (24%). In the literature reviewed, sides of injury were not indicated, thus comparisons could not be made, however the propensity for the left sided injuries is likely because most assailants are right handed[37]. There were less differences in the sides of injuries from GSW with 16 injuries on the right (44.4%) and 12 (33.3%) on the left and suggests that the site of GSW injury is less dependent on hand dominance.

### 6.1.1. Strengths and limitations

This is the first study in the literature we researched looking at the relationship between the imaging modalities in patients with PNI's and the time interval between requests and report for contrast swallow.

A large portion of patients with contrast swallow in the period of interest was excluded (60.7%) as they did not meet all the required imaging criteria. However, the cohort size of 153 is still one of the largest series reported in the literature. Individual comparisons of the lateral soft tissue neck radiograph versus the contrast swallow (gold standard) and MDCTA vs contrast swallow could also have been investigated separately as this may improve accuracy. Furthermore, MDCTA was used as a screening tool for vascular injuries, which may result in sampling bias for PNI.

The study is a radiological perspective and does not include surgical management. See recommendation below (3rd paragraph in 6.1.2.).

For assessment of delay in the contrast swallow investigation. The logged time on the radiology reports was used against the time indicated on the electronic requests. The former was used instead of the actual time indicated on the fluoroscopy images on PACS as these were inaccurate and the clock was not synchronized to real time. Generally, in our institution with a few exceptions, there is no delay in releasing the reports after the procedure. It is also noted that there may be cases where a verbal report may have been given prior to completion of the radiology report, this is however not common practice and is thought not to be significant to affect the overall calculated time delay.

### 6.1.2. Implications or recommendations

There has been interval improvement in expediting contrast swallow investigations at Groote Schuur Hospital, by introduction of extra radiology registrars in the evenings, weekends and public holidays. It will be of interest to evaluate whether the delay in performing this crucial investigation has improved.

Factors contributing to the delay between the request of the contrast swallow to the radiology report were beyond the limits of this study. As this is an important factor in the final management of the patient, this has to be analysed further.

A study exploring collaboration of the imaging modalities from the radiological department and the SNOM management of PNI's from the surgical discipline (see paragraph 7.1.2 'Literature Review') may be ideal so as to propose a more comprehensive management algorithm, suitable for both departments and providing the ultimate efficient management of these injuries. This will also be more objective

if a standardised reporting template for MDCTA's can be introduced that requires specific mentioning of likelihood of or less likelihood of POI

## 7. Conclusion

PNI's are common in patients presenting at Groote Schuur Hospital and are caused by injuries related to violence which is high in South Africa. Although only a small percentage of these injuries result in POI's, associated complications results in significant morbidity and mortality. The most significant cause of complications is the delay in final management and the preliminary investigation such as the contrast swallow. This study found significant delay between requesting the contrast swallow and the report. This adds to the overall delay in final management of the patient and the actual causes of these delays needs to be investigated further and improved.

Presence of prevertebral air on lateral soft tissue has little contribution in the diagnosis of PPOI's, although absence of air may suggest less likelihood of PPOI's this has to be correlated with clinical findings. MDCTA's also has very low specificity and thus cannot provide adequate contribution to the diagnosis of POI. The above imaging modalities did not demonstrate reliable diagnosis of PPOI's and thus, contrast swallow remains the 'gold standard' in diagnosis PPOI's in patients with PNI's.

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# III. Addenda

## Addendum 1 - Original Ethics Approval

**UNIVERSITY OF CAPE TOWN**
**Faculty of Health Sciences**
**Human Research Ethics Committee**

**Room E53-46 Old Main Building**
**Groote Schuur Hospital**
**Observatory 7925**
**Telephone** [021] 406 6492
**Email:** sumayah.arieffdien@uct.ac.za
**Website:** www.health.uct.ac.za/fhs/research/humanethics/forms

15 November 2017

**HREC REF: 795/2017**

**Dr T Pennel**
Division of Cardiothoracic Surgery
Department of Surgery
OMB

Dear Dr Pennel

**PROJECT TITLE: IS THERE A ROLE OF CTA IN CERVICAL OESOPHAGEAL INJURIES? (MMeD-candidate-Dr F M Oompie)**

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee (HREC) for review.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

**Approval is granted for one year until the 30 November 2018.**

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

***We acknowledge that the student: Dr F Oompie will also be involved in this study.***

**Please quote the HREC REF in all your correspondence.**

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval, where necessary, before the research may occur.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE

Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938

HREC 795/2017

## Addendum 2 – Extension of Ethics Approval


UNIVERSITY OF CAPE TOWN

FACULTY OF HEALTH SCIENCES
Human Research Ethics Committee

### FHS016: Annual Progress Report / Renewal

| HREC office use only (FWA00001637; IRB00001938) This serves as notification of annual approval, including any documentation described below. | | | |
|---|---|---|---|
| ☑ Approved | Annual progress report | Approved until/next renewal date | 30.11.2019 |
| ☐ Not approved | See attached comments | | |
| Signature Chairperson of the HREC | | Date Signed | 16/11/2018 |

| Comments to PI from the HREC |
|---|
| |

**Principal Investigator to complete the following:**

**1. Protocol Information**

| | | | |
|---|---|---|---|
| Date (when submitting this form) | 06/11/2018 | | |
| HREC REF Number | 795/2017 | Current Ethics Approval was granted until | 30/11/2018 |
| Protocol title | **The Role of Computerised Tomographic Angiograms and lateral Neck Radiographs in Penetrating Neck Oesophageal Injuries** | | |
| Protocol number (if applicable) | | | |
| Are there any sub-studies linked to this study? | ☐ Yes ☑ No | | |
| If yes, could you please provide the HREC Ref's for all sub-studies? **Note:** A separate FHS016 must be submitted for each sub-study | | | |
| Principal Investigator | Dr Tim Pennel | | |
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| 1.1 Does this protocol receive US Federal funding? | ☐ Yes | ☑ No | |



(Note: Please complete the Closure form (FHS010) if the study is completed within the approval period)