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EMERGENCY ROOM ARTERIOGRAPHY: AN UPDATED DIGITAL TECHNOLOGY

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ABSTRACT

Background: **Emergency room arteriography (ERA) is a safe, accurate, simple and cost-effective method of defining arterial injuries. Limitations include the difficulty of evaluating limb vasculature distal to the suspected site of injury. Statscan is a novel, low-dose digital X-ray machine that can rapidly obtain a whole body image in a single scan. Our goal was to evaluate the role of Statscan technology in ERA.**

Methods: **A 24 month retrospective review of all patients who underwent a Statscan assisted ERA at the Groote Schuur Hospital Trauma Unit was completed. Indications for ERA included a hemodynamically stable patient with hard signs of a vascular injury in conjunction with the clinical assessment of a threatened limb. Contraindications encompassed instability, massive bleeding or a rapidly expanding hematoma.**

Results: **Ten patients underwent Statscan assisted ERA of their lower limbs. Eight had cold, pulseless limbs with impaired neurological examinations. Common femoral, superficial femoral and popliteal artery lacerations were displayed. Three patients had no identifiable injury and were observed. Seven patients underwent operative management for threatened limbs. Two had Statscan evidence of arterial emboli distal to the site of injury leading to further exploration and distal embolectomy.**

Conclusions: **Statscan ERA is safe, rapid, simple and accurate. It has the advantage of providing arteriography distal to the site of injury. This directly altered patient care in 20% of cases, primarily by detecting distal arterial emboli. Thirty percent of patients with normal ERA also avoided an unnecessary operation. This study demonstrates a new role for Statscan technology.**

Key words: Emergency room arteriography; vascular trauma; digital X-ray; penetrating trauma; threatened limb; Statscan

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INTRODUCTION

Emergency room arteriography (ERA) is a simple, safe and cost-effective method of defining traumatic peripheral vascular injuries (1–3). With a sensitivity and specificity of 95.5% and 97.7% respectively (2), its accuracy is also superior to most non-invasive, vascular diagnostic tests (4). Although there is still debate surrounding the appropriate indications for its use (1,5), absolute contraindications are clear. Patients with hemodynamic instability, massive bleeding and/or a rapidly expanding hematoma require urgent operative intervention, not additional investigations.

Since its initial description in 1958, ERA has undergone few significant technical modifications (6). It still consists of a single manual injection of intra-arterial contrast with subsequent radiographic imaging. It is also typically performed by the emergency department staff without the need for either a trained vascular radiologist, or patient transport to an angiography suite (1). Although the simplicity of ERA remains one of its core strengths, it also highlights the procedure's weakness. With the use of single image radiographs, it is difficult to evaluate vasculature distal to the site of suspected injury. This would require radiographic cassette repositioning, as well as repeat contrast administration. It was this limitation that prompted the use of a new digital x-ray machine in performing ERA.

The Statscan machine (Lodox Ltd, Industrial Development Corporation, Johannesburg, South Africa) is an FDA approved, novel emergency department digital imaging tool that utilizes low dose, fan beam x-ray technology to provide rapid full body images. This machine has been shown to be diagnostically equivalent to conventional radiographs in terms of image quality, but superior with regards to digital technology, overall efficiency, and long-term cost (7). Although the Statscan also possess the advantages of speed of acquisition, patient accessibility during active resuscitation, and excellent bone and soft tissue imaging, it was the low radiation dose; full body imaging characteristics that suggested it had a potential role in ERA applications. The goal of this project was therefore to evaluate the use of the Statscan machine in ERA.

Fig. 1. Statscan machine.

MATERIALS AND METHODS

The Groote Schuur Hospital Trauma Center, based in Cape Town, South Africa, is an adult referral trauma center serving the greater metropole and surrounding areas. Most patients are victims of penetrating trauma.

A retrospective review of all patients who underwent an emergent arteriogram using the Statscan machine at the Groote Schuur Hospital between April 1, 2003 and April 1, 2005 was completed. Data was compiled from individual patient records, as well as Statscan image archives. Independent variables included patient age, sex, hemodynamic status at presentation, mechanism of injury, length of hospital stay, injury severity score, concurrent injuries, physical examination and limb status, indications for Statscan ERA, complications (hematoma and contrast medium extravasation), site and extent of vessel injury, patient management and limb function at the time of discharge.

Indications for ERA included a hemodynamically stable patient with hard signs of a vascular injury (pulseless limb, bruit or pulsatile haematoma) and the clinical assessment of a potentially threatened limb. Pulseless limbs were identified with the use of both digital palpation, as well as hand-held portable Doppler ultrasound. Patients with diminished pulses or shotgun injuries, and a viable limb, underwent formal angiography in the vascular radiology suite. Contraindications for ERA encompassed hemodynamic instability, massive bleeding or a rapidly expanding hematoma.

ERA using the Statscan machine was performed in the resuscitation suite exclusively by the emergency unit staff. After being placed on a resuscitation table designed specifically for the Statscan unit, an 18 gauge plastic intravenous cannula was inserted in retrograde fashion into the common femoral artery via direct puncture. An intravenous extension set was then attached to the cannula to aid in positioning the operator's hands away from the visualized area. Thirty millilitres of a non-ionic, water soluble iodinated contrast material (Ultravist 300, Schering Ltd., Berlin, Germany) was rapidly injected by hand into the artery. The Statscan machine was then activated to image the limb just prior to completion of the contrast bolus. A digital image of the arterial system was available for interpretation within 13 seconds. Typically, this procedure required less than 10 minutes to complete in its entirety. If needed, lateral and/or oblique views could be obtained as well.

The Statscan machine consists of an x-ray tube mounted on an axially rotating C-arm that produces a collimated fan beam of low dose x-rays (Fig. 1). An X-ray detector comprised of scintillator arrays linked to charge coupled devices (CCD) is situated on the opposite side of the C-arm. An image is taken by scanning the C-arm over the whole body, or required anatomical region of the patient, while reading the continuous detector output. The C-arm itself travels at 14 centimetres per second, allowing for the rapid acquisition of X-rays. The mean digital radiation dose has been measured as low as 6% that of conventional X-rays (7). The image is displayed on a computer controlled operating and viewing system with standard Digital Imaging and Communication in Medicine 3 (DICOM 3) capability.

Mean, median and range were calculated using stan-

dard methodology. Data were reported as a mean when normally distributed and as a median when non-normally distributed.

RESULTS

During the 24-month study period, ten patients underwent ERA using the Statscan machine. Patient demographics and injury details were representative of the typical trauma patient cohort treated at Groote Schuur Hospital (Table 1). All patients had imaging of their lower limbs with intra-arterial contrast administration via the common femoral artery.

Physical examinations of the patient's limbs were abnormal in each of the 10 cases. Eight cases had cold, pulseless limbs with impaired neurological examinations (reduced sensory and/or motor function). Two additional patients had cold and pulseless limbs, but intact motor and sensory neurological status. These two patients both had isolated stab wounds to the medial portion of their lower limb. Indications for ERA in all patients were an abnormal physical examination consistent with a threatened limb (cold and pulseless).

Vascular injuries included common femoral, superficial femoral and popliteal artery lacerations, as well as transections of the popliteal and femoral veins (Table 2). Four patients had complete arterial transections and three had partial lacerations (Fig. 2). Each partial laceration was greater than 60% of the vessel circumference. Three patients who underwent ERA had no identifiable injury at the site of interest. Four patients also had additional injuries remote to the threatened limb. Two had severe abdominal injuries (one with an associated moderate head injury); one had a chest injury and another had a soft tissue injury secondary to a gunshot wound in the contralateral limb (Table 2). The hemopneumothorax was treated with an intercostal drain, and the abdominal injuries were repaired via laparotomy. Two patients had fractures associated with their arterial injuries (Table 2). All fractures were treated with intramedullary nails or internal fixation plating systems.

Seven patients underwent operative management for threatened limbs after the Statscan ERA (Table 3). All six patients who had arterial repairs displayed intact distal pulses via Doppler ultrasound at the conclusion of the procedure. Among the operative cohort, Statscan ERA also revealed two patients with evidence of arterial occlusion distal to the site of injury (Fig. 3). This lead to further exploration and distal embolectomy in both cases. In spite of a grossly abnormal initial physical examination, 3 patients were successfully observed non-operatively after a normal ERA (Fig. 4).

Although long-term follow-up was limited to patients with functional issues, eight had normal limb function at the time of discharge from hospital. One patient had a residual foot drop. The remaining patient had an above the knee amputation. This patient had a complete SFA transection secondary to a gunshot wound to the right thigh. He underwent emergent SFA and SFV ligation, as well as upper and lower limb fasciotomies that revealed clinically two dead compartments. Preoperatively, the possibility of requiring an amputation was discussed with the patient, however he refused to provide consent. On postoperative day 2, the patient agreed and was returned to the operating theatre for an AKA. Two pa-

TABLE 1

Patient demographics and data [N = 10]

Patient age	Mean 41 (range17–43) years
Male gender	8
Mechanism of injury	
Gunshot	6
Stab	3
Motor vehicle collision	1
Injury Severity Score	
Median	25 (range 4–50)
Patients with other injuries	2
Length of hospital stay	
Median	6 (range 1–39) days

TABLE 2

Patient injuries-

Vascular Injuries	
Common femoral artery	2
Superficial femoral artery	3
Popliteal artery	2
Distal embolization	2
Superficial femoral vein	1
Popliteal vein	1
Chest Injuries	
Hemopneumothorax	1
Abdominal injuries	
Small bowel perforation	1
Mesenteric laceration	2
Liver laceration	2
Stomach laceration	2
Duodenal laceration	1
Ureteric transection	1
Pancreatic contusion	1
Gallbladder laceration	1
Retroperitoneal haematoma	2
Orthopaedic injuries	
Femoral fracture	2
Tibia and fibula fractures	1

TABLE 3

Vascular injury management.

Arterial injuries	
Primary repair	3
Saphenous vein interposition graft	2
Synthetic interposition graft	1
Ligation with above knee amputation	1
Venous injuries	
Ligation	2
Associated fasciotomies	4
Embolectomy	2
Non-operative observation	3

Fig. 2. Statscan ERA displaying a traumatic fistula between the superficial femoral artery and vein.

Fig. 3. Statscan ERA after a tab wound with an injury to the popliteal artery and embolic occlusion of the peroneal and anterior tibial arteries.

Fig. 4. Normal Statscan ERA.

tients had normal ERAs concurrent to cold, pulseless limbs and neurologic impairment. Both patients had an excellent functional outcome with no residual deficits. The cause of their initial neurologic impairment is unclear.

Statscan test performance revealed no missed injuries (i.e. false negatives) in patients who underwent an operative procedure, as well as a specificity of 100%. Clinical examination suggestive of a threatened limb (cold and pulseless) was predictive of significant vascular injury requiring operative intervention in 7 of 10 (70%) cases. There was also no morbidity associated with the Statscan ERA. Furthermore, no significant delay was noted in those patients who eventually proceeded to operative repairs.

DISCUSSION

Arteriography is an important tool in the selective evaluation of suspected peripheral vascular injuries in many busy trauma centers (8-11). Although formal digital subtraction angiography in the radiology suite is extremely accurate, it has the disadvantage of being costly and time consuming (12, 13). Transfer of the critically injured patient out of the emergency department is also required. ERA has repeatedly been shown to be a sensitive, accurate and inexpensive test for identifying peripheral vascular injuries (1–3). It has the advantage of being rapid, readily available and simple in nature. This allows the test to be performed within the emergency department itself, and by relatively inexperienced operators (1–3). In spite of these benefits, ERA disadvantages include the inability to image limb vasculature distal to the area of concern with a single injection. To visualize the entire limb, individual distal exposures must be stitched together. This process is associated with time delays and equipment repositioning, as well as an increased radiation dose, intra-arterial contrast load, and overall technician workload.

The Statscan machine at the Groote Schuur Hospital is located in the trauma resuscitation room and provides partial, and/or whole body, digital x–rays of all significantly injured patients within a single scan. This technology is most impressive for patients undergoing concurrent resuscitation, where the time to image completion approximates 6 minutes (7). This compares to 48 minutes with a conventional system (7). The ability of the Statscan machine to move along the patient at different axial angles in a rapid manner prompted the investigation into its utility for ERA. This technical feature is particularly important in accounting for the procedure's false negative rate, as up to 70% of all diagnostic errors in ERA occur when only a single view is attained (14). Furthermore, because of the Statscan's ability to collect all data on a single scan, significantly less radiation and intra-arterial contrast is required. This is supplementary to the benefit of an up to 98% reduction in radiation exposures on an image-by-image basis. In addition to retaining all of the advantages of traditional ERA, including providing a road map for future surgical therapy, the Statscan is also able to image bone and soft tissue structures with its extended field of view (7). This added diagnostic imaging of bony structures was particularly helpful in assessing the two of our patients with associated fractures. Each fracture required operative therapy. Finally, screening patients for final bullet locations and trajectories is also important in a trauma unit where the most common mechanism is penetrating injury.

Although some authors reserve the use of ERA for patients with soft signs of vascular injury (history of bleeding, injury in proximity to a major vascular structure, small non-expanding hematoma or diminished pulse), advocating emergent therapy for all cases with hard signs (absent pulse or bruit) (1–3), we utilise the Statscan ERA in patients with examination findings consistent with a threatened limb (absent pulse, bruit or cold limb). Patients with soft signs of vascular injury, or a shotgun mechanism, undergo

formal angiography by a vascular radiologist. This philosophy is based not only on the importance of pre-operative planning for surgical exposure and repair, but also on the reality that false positive physical examinations suggesting limb jeopardy are not uncommon (1, 2, 15). In our study, three patients had a cold and pulseless limb with no identifiable injury on subsequent ERA. Each of these patient was managed conservatively, avoiding an unnecessary peripheral limb surgical procedure. Two of these patients also had extensive abdominal injuries requiring urgent operative repair. The preceding normal ERA allowed the operative team to focus on the abdominal injuries without the need for concurrent, or subsequent, operative care of the limb. The other patient had no other injuries and was discharged home within 20 hours. As expected, all patients with hemodynamic instability, massive bleeding and/or a rapidly expanding hematoma were not suitable for ERA with Statscan. These patients underwent emergent operative procedures.

Because conventional ERA is highly effective, our study attempted to identify those patients who had specific alterations in their management as a direct result of the Statscan application. In addition to the three patients whose arteriograms were normal, Statscan ERA identified two cases of arterial occlusion distal to the site of injury. Operative management was changed in both patients to include a more extensive exploration, as well as a distal embolectomy. Both patients had embolized a significant amount of clot resulting in complete occlusion of downstream arteries. This alteration in operative management was a direct result of the Statscan's ability to image vessel status distal to the site of injury. Although it could be argued that inevitable intra-operative exploration and/or angiography would have eventually determined the cause of persistently absent distal pulses after a proximal arterial repair, Statscan made the associated pathology evident pre-operatively. This enabled the procedure to be performed in an efficient manner, minimizing both operative and anaesthetic risks to the patient. Unfortunately, intra-operative arteriography, like formal radiologic angiography, is far more time consuming than pre-operative Statscan ERA. Itani and colleagues have echoed this observation of on-table angiography as well (2).

As previously stated, patients with arterial trauma may, or may not, present with classic findings that make the diagnosis obvious. Diagnostic options include mandatory operative exploration, arteriography, and ultrasonography. Although operative exploration is considered the gold standard, Doppler and duplex sonography is also valuable for diagnosing peripheral vascular injuries. While this modality is non-invasive, and extremely specific (100%), it's sensitivity approximates only 91% (16). There is also evidence that duplex ultrasonography may be limited in detecting injuries in patients who do not display obvious clinical signs of arterial injury (sensitivity = 83%) (16). Although equipment resources impact both diagnostic options, operator experience is clearly more crucial to the interpretation of duplex ultrasonography. Furthermore, in our hospital, the Statscan machine is available at all times, whereas the availability of duplex ultrasonography is time of day and operator dependent.

In conclusion, the Statscan ERA is safe, fast, simple, cost-effective, and does not significantly delay subsequent operative therapy. It also has the advantage of high quality concurrent imaging of the patient's bony and soft tissue anatomy, in addition to providing arteriography distal to the site of injury. In our series, the use of Statscan technology directly altered patient care in two cases. This was primarily a result of detecting distal arterial emboli, which in turn altered the operative strategy. This is supplementary to the three patients with normal ERAs who avoided an unnecessary operation. This study demonstrates a new role for the Statscan machine in addition to its primary role of obtaining rapid whole body X-rays.

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