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Case Report

Utilization of bone scan and single photon emission computed tomography on amputation planning in acute microvascular injury: Two cases

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ABSTRACT

The use of single photon emission computer tomography (SPECT/CT) in acute vascular injury is not well documented. SPECT/CT combines the anatomic detail of computer tomography with the functional vascular perfusion of photon emission to determine the viability of osseous structures and surrounding soft tissue. The superimposed imaging provides the practitioner with a reliable anatomic image of viability of a specific anatomic area following insult or injury. We present two cases, bilateral lower extremity frostbite, and symmetric peripheral gangrene in which this imaging modality provided guidance for surgical intervention with adequate predictability and results.

1. Introduction

Single photon emission computed tomography (SPECT/CT) combines the use of a radiotracer to visualize functional blood flow to tissues and organs with the anatomically detailed cross sectional images of a computerized tomography scan. Three distinct displays are produced: an x-ray CT image, a radionuclide emission image, and a superimposed image with radionuclide data displayed in color over the CT scan [1]. The anatomical data is thus used to localize radiotracer uptake and assist in SPECT diagnosis.

Our aim is to further contribute to the available literature on acute vascular injuries and raise physician awareness of current innovative diagnostic and planning modalities to aid in surgical intervention. Our goal for these case reports is to give physicians two examples of the use of bone scan and SPECT/CT in amputation planning. Our first case involved bilateral foot necrosis secondary to frostbite. The second case consisted of bilateral foot and bilateral hand necrosis following vasopressor treatment for septic shock caused by a perforated gastric ulceration

1.1. Frostbite

Frostbite is the latest and most severe complication within the spectrum of cold injury. Its manifestations include anesthesia, limb discoloration, and tissue freezing [2]. Cold injury is due to a prolonged exposure to a low absolute temperature, and damage to the affected extremities range from reversible numbness to permanent tissue damage [2].

Classically, there are four phases of cold induced thermal injury [2]. The first phase is hallmarked by local vasoconstriction with resultant paresthesia leading to a superficial skin desquamation. The second phase involves intracellular and extracellular ice crystal formation that damages cell membranes and leads to a partial thickness injury to the skin with vesiculation. The third phase involves endothelial damage with full thickness skin injury and hemorrhagic blisters with eventual ulceration. This is due to prolonged local vasoconstriction that leads to coagulation, hypoxia, and acidosis. The fourth phase is triggered by inflammatory mediators that promote additional vasoconstriction, platelet aggregation, and vessel thrombosis. Full thickness damage to the skin including bone may be seen in the fourth phase [2].

First aid treatment of cold injury is to use body warmth (patient's own or another) to re-warm the affected area. Definitive re-warming should be in a water bath at 40–42 C (tolerable to the back of the hand). If necessary, thrombolytic therapy may be able to reverse the vasoconstriction induced thrombosis and thus re-establish distal perfusion. In cases of severe frostbite not amenable to conservative and non-invasive therapies, surgical debridement and amputation should be planned and performed expediently [2].

1.2. Symmetrical peripheral gangrene

Symmetrical peripheral gangrene (SPG) is defined as ischemic limb necrosis affecting at least two distal extremities in equal fashion. SPG commonly occurs in the presence of doppler identifiable peripheral

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Fig. 1. Initial presentation to emergency department following long term exposure to cold (two days).

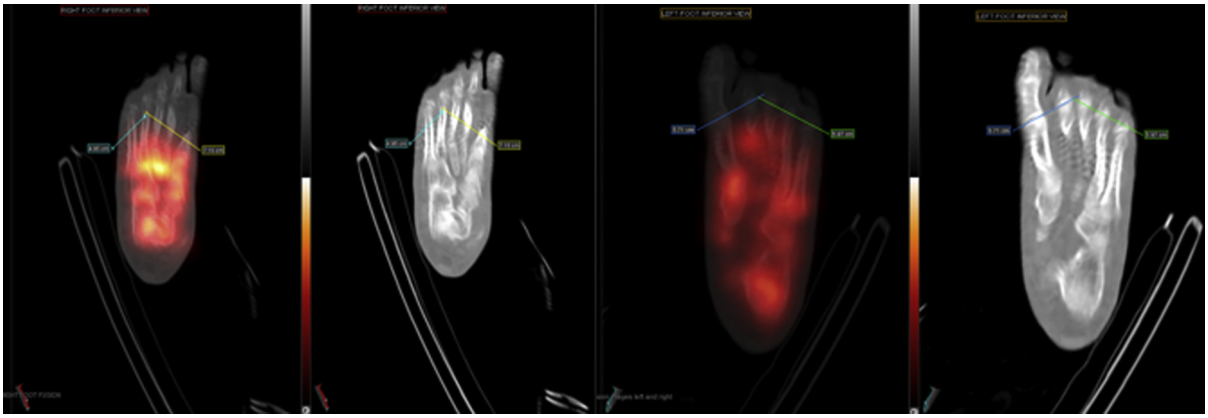

Fig. 2. SPECT/CT imaging demonstrates lack of bone or soft tissue uptake beyond the distal metatarsals of the left foot. The activity tapers sharply just proximal to the metatarsal heads. There is no bone or soft tissue uptake beyond the mid portion of the metatarsals of the right foot.

Fig. 3. Guillotine transmetatarsal amputation following development of acute infection to the right foot. The level of amputation was performed distal to uptake on the PET/SPEC CT with plans for revisional surgery.

arterial pulses, and in the absence of proximal arterial obstruction [3]. Symmetrical peripheral gangrene is an extremely rare complication associated with critically ill patients; many of whom are hypotensive, in sepsis, and treated with vasopressors and inotropic pharmacological agents such as dopamine or norepinephrine [4]. In some cases, ischemic changes may also affect the nose, ear lobes, upper lips, and genitalia [4]. SPG has also been reported in a multitude of clinical scenarios including but not limited to chickenpox [5], measles [6], ergotism [7], postpartum [8], post-surgery [9], malaria [10], snake bite [11], pancreatitis [12], and dengue fever [13].

The vasoactive medication currently recommended by the Surviving Sepsis Campaign guidelines as a first line vasopressor is norepinephrine with dopamine suggested as an alternative agent [14]. Norepinephrine acts to increase mean arterial pressure via vasoconstriction with less effects on heart rate and stroke volume when compared with dopamine. Recent literature studying the use of norepinephrine versus dopamine for the treatment of septic shock has thus shown a lower mortality rate and lower risk of arrhythmias with norepinephrine [15]. Increased doses of vasopressors, however, may lead to extreme vasoconstriction in the peripheral arterioles and tissue hypoperfusion due to vasospasm [16]. Another hypothesis is platelet plugging due to disseminated intravascular coagulation (DIC) [17]. Although this phenomenon has been previously reported, the pathophysiology remains poorly

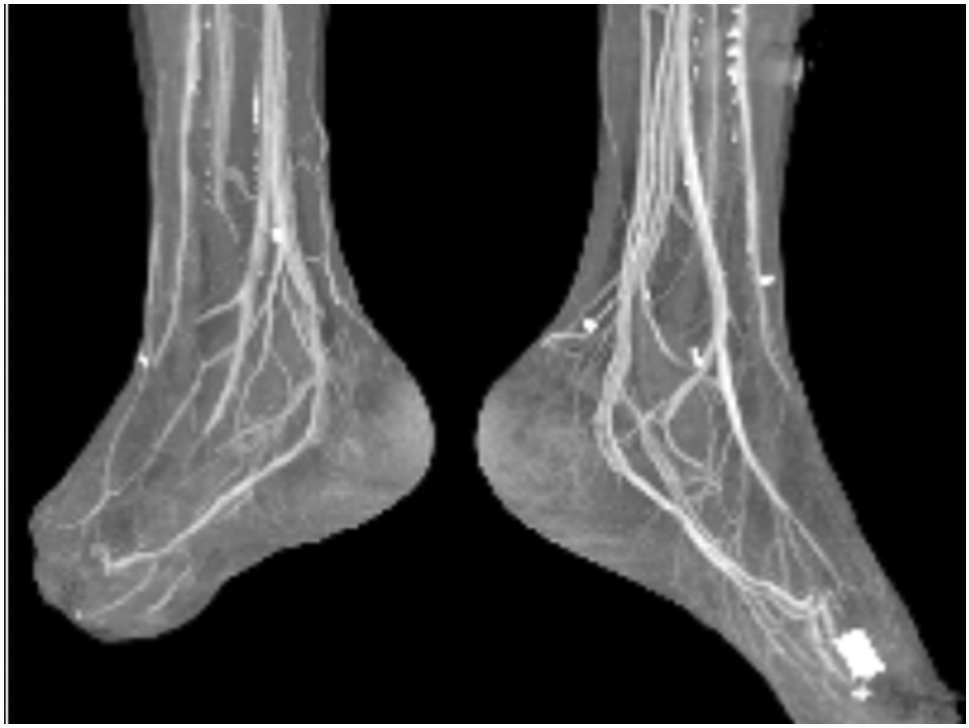

Fig. 4. CT angiogram of bilateral feet noting patent proximal arterial perfusion to the hindfoot and midfoot as part of preoperative planning.

Fig. 5. 3 months status post frostbite injury with wound closure. The patient was discharged and could weight bear as tolerated.

Fig. 6. 2 years status post frostbite injury free of ulceration with ambulation maintained.

Fig. 7. Early ischemic changes seen in symmetrical peripheral gangrene following the use of vasopressors on s/p laparotomy day #7.

understood [18].

1.3. Triphasic bone scan and PET utilization

A triphasic bone scan is performed to fully differentiate non-viable tissues from well vascularized portions of each lower extremity. Viable tissue would be depicted as a "hot spot" with hyperemia, increased perfusion, and increased soft tissue uptake. Nonviable tissue would be visible as a "cold spot" and appear as a defect with little to no perfusion apparent in all three phases [19]. A purely clinical determination of the approximate level of gangrene may miscalculate the extent of irreversible soft tissue injury. Clinical misjudgment may lead to unnecessary extensive proximal amputation or revision surgery due to an amputation at a level too far distal. The incorporation of SPEC/CT with triphasic bone scan provides anatomic delineation that further aides surgical planning in these cases [20]. The utilization of triphasic bone scan or SPECT/CT in the presence of acute vascular injury allows for earlier surgical planning with resultant early intervention [20]. The benefit for the patient is a decreased risk of infection, shorter hospitalization, and an earlier rehabilitation [20]. In both included cases, functional viability was determined based on advanced imaging, guiding the surgeon to confident amputation margins with adequate soft tissue coverage.

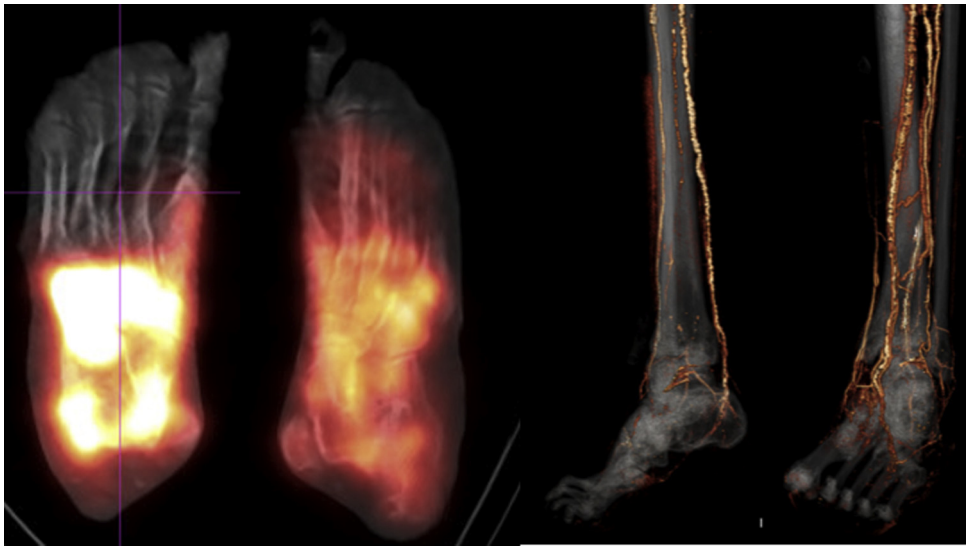

Fig. 8. Preoperative planning following symmetric peripheral gangrene. Tri-phasic bone scan with PET/SPEC CT demonstrates viability to the level of Lis franc's joint on the left foot and to the midshafts of the metatarsals on the right foot. CT angiogram was obtained for flap based closure.

2. Case presentations

2.1. Case #1

A 40 year male presented to the NYU Brooklyn Hospital emergency department after sleeping in a park for two days following alcohol intoxication in December of 2016. The patient had no past medical history. The patient described a purple discoloration with throbbing to their feet. Objectively the patient had palpable pedal pulses with no capillary return to the digits. Each forefoot was cool to touch and grossly edematous. Neurologically, fine touch sensation (using a Semmes Weinstein monofilament) was absent to the level of the tarsometatarsal joints bilaterally. The forefeet appeared dusky with fissuring to each toe sulcus with discoloration extending to the midfoot bilaterally at the dorsal aspect of the foot. The discoloration extends across the entire plantar foot bilaterally. Flexion and extension while guarded was intact with limited passive and active range of motion (Fig. 1).

Initial vital signs were stable. Routine laboratory values revealed a mildly elevated white blood cell count (12.2 10*3/uL) and most notably increased creatine phosphokinase (4864 IU/L). The patient was admitted to the hospital for observation. Luke warm soaking in a betadine saline solution was initiated. Unasyn was started as empiric antibiotic therapy. At day five the patient underwent Triphasic bone scan with PET/SPECT overlay for surgical planning (Fig. 2). At day 12 the patient became febrile and tachycardic with an increased white blood cell count. Heavy purulent drainage was expressed from the right foot. The patient underwent a guillotine transmetatarsal amputation that evening (Fig. 3). At this time due to infection, distal necrosis was debrided proximally to visibly healthy tissue. A CT angiogram was obtained prior to revisional surgery to determine the basis for flap closure of the distal amputation stumps (Fig. 4). It was noted that the medial calcaneal artery to both feet was acutely stenosed which correlated with a dry gangrenous eschar to the heels of both feet. At two weeks the patient underwent revision of the right foot guillotine amputation and primary amputation of the left forefoot. The right foot amputation was revised to an intercuneiform amputation using plantar musculature for distal stump coverage. Level of boney resection was correlated with the findings of the Triphasic bone scan with PET/ SPEC CT. The left foot amputation stump epithelialized and healed without complication. At 4 weeks the patient underwent harvest and application of split thickness skin grafts from the bilateral thighs. The harvested skin was applied to the distal amputation stump of the right foot as well as the left heel. A tendoachilles lengthening was not performed as the patient had adequate dorsiflexion in knee extension and flexion. The patient remained hospitalized due to his undomiciled status and inability to perform wound care. The patient was discharge at 3 months with wound closure obtained and ambulatory status intact (Fig. 5). The patient was recently seen in the emergency department (2 years after discharge) for acute alcohol intoxication, the amputation stumps remain intact and wound free with minimal hyperkeratotic tissue over their distal aspects (Fig. 6).

2.2. Case #2

A 66 year old male presented to the NYU Brooklyn Emergency Department in the summer of 2018 with chief complaint of 24 h urinary retention and abdominal pain. Past medical history included coronary artery disease, sick sinus syndrome, Hepatitis C and spinal stenosis. Past surgical history included cardiac stenting, ablation, pacemaker (2014), achilles tendon repair (2009), shoulder arthroscopy and total hip arthroplasty (2009) with revision (2016). Chest radiograph revealed free air under the diaphragm and patient was taken for exploratory laparoscopy. Laparoscopy was converted to open laparotomy due to copious feculent leakage into the abdominal cavity with copious lavage and insertion of Malecot drain. The immediate postoperative recovery required high mechanical ventilation do to hyperkalemia, acidosis, and hypotension, placed on continuous veno-venous hemofiltration (CVVH) with multiple pressers.

On postoperative day #7 early ischemic changes were seen in the distal extremities (Fig. 7). Pedal pulses were palpable, an initial capillary return was delayed but present. A triphasic bone scan with PET/SPECT was obtained to assist in determining the extent of tissue viability for preoperative planning and limb prognosis. CT angiogram was performed to assess patency of major vessels (Fig. 8). Following medical stabilization the patient underwent Lisfranc amputation of the left foot and transmetatarsal amputation of the right foot with partial hand amputations approximately two weeks after the initial laparotomy. The left foot was loosely approximated and the right foot was primarily closed. A cadaveric split thickness skin graft was applied to the distal stump of the left foot once adequate granulation tissue developed (Theraskin™). A 6 week course of antibiotic therapy was given for confirmed acute osteomyelitis from the resection margins of the hand. The patient was permitted to ambulate on his heels. The patient was

Fig. 9. Wound closure at 4 months following primary amputation. The patient now ambulates with the assistance of a rolling walker.

subsequently taken for excision of exposed bone and primary closure of the wound one month following the initial procedure. The right foot required application of cadaveric split thickness skin graft (Theraskin™) performed in the office setting. The patient went on to physical therapy once ulcerations were closed four months after the initial procedures (Fig. 9). The patient now ambulates with a rolling walker with the intention to progress to a cane.

3. Discussion

Acute microvascular injury to the distal extremities from frostbite and symmetric peripheral gangrene can severely impair function and require prolonged hospital stay and medical care. Historically, these injuries were treated by letting soft tissue demarcate and only intervening surgically in the presence of infection or many months after the initial injury. Two cases are presented with separate etiologies of microvascular injury where surgical planning was assisted by utilizing bone scan with PET/SPEC CT imaging. Both patients went on to heal and ambulate earlier than what is described in the literature [22]. In both cases a CT angiogram was performed to determine which angiosome was best perfused for flap closure. The use of this imaging modality concomitantly with bone scan with PET/SPEC CT assisted us in determining osseous and soft tissue viability.

Previous literature has cited successful outcomes in 84% of limbs amputated at levels according to bone scan findings [22]. In cases with an indistinct gangrenous demarcation, bone scan is an exceptionally valuable tool to reduce ambiguity. An additional consideration when utilizing bone scans is the timing of the procedure. Bone scans performed too early may depict a false level of demarcation between vascularized and necrotic tissue. Gard and colleagues advise performing bone scans 2–4 days after the original injury in cases of frostbite [22]. Moreover, In a recent study by John et al. [19], extremities with frostbite were evaluated with SPECT/CT scans to determine viable tissue prior to digital amputation. The authors noted that none of the patients required revision amputation beyond the level predicted on SPECT/CT scan [23]. Manganaro et al. also published recently on expedited treatment of frostbite and accuracy of amputation using SPEC/CT [24].

In comparison, a similar case of symmetric peripheral gangrene was reported by Axman et al. in 2018. In this case, the primary surgical

procedure was delayed 5 months with multiple hospital admissions, courses of antibiotic treatment, as well as several surgical procedure. At one year the patient had not healed the bilateral foot wounds [25]. In contrast our patient with symmetric peripheral gangrene underwent two surgical procedures (for their feet). The primary procedure occurred two weeks after the onset of injury. One emergency room visit occurred for suspect recurrence of small bowel obstruction, and outpatient antibiotics were given for osteomyelitis of the hand, as the foot resection margins were negative.

4. Conclusion

Bone Scan PET/SPEC CT may be a useful compliment in assisting the physician in determining amputation level. Two cases are presented frostbite and symmetric peripheral gangrene in which this imaging modality was used to supplement clinical findings and establish a higher degree of confidence in level of osseous and soft tissue resection. Additional evidence could be obtained to determine the role of bone scan SPECT/CT in acute microvascular injury to improve patient outcomes.

Conflict of interest

None.

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