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Evaluation of arterial obstructive leg and foot disease by three-phase bone scintigraphy

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Background: The level selected for amputation should generally be the lowest compatible with tissue viability, with a reasonable expectation of wound healing in patients with arterial obstructive leg and foot disease, but determining the amputation level of an ischemic lower limb remains controversial. The general consensus is that a decisive and final decision about the amputation level should be made intraoperatively based on the extent of hemorrhage from the incised skin and soft tissue, and the degree of viability of the stump.
Objective: To estimate the extent of such hemorrhage, and thus suggest the level of amputation preoperatively, the author applied three-phase bone scintigraphy (TPBS) to assess the blood flow in the small arteries and capillary vessels.
Method: TPBS was performed in patients scheduled to undergo lower limb amputation in an attempt to determine the appropriate amputation level preoperatively, objectively, and visually. Imaging results of this examination were compared with the clinical findings in three cases of arterial obstructive foot disease.
Results: The "capillary phase" depicted the perfusion of blood from the small arteries to the capillary vessels. Decreased accumulation in the capillary phase appeared as two distinctive states: one of clinically remarkable necrosis and the other of decreased blood flow in the small arteries and capillary vessels. The latter inevitably causes necrosis and infection postoperatively.
Conclusion: The results of this study suggest that TPBS is an extremely useful tool in the evaluation of physiological dysfunction and the likely amputation level in patients with arterial obstructive leg and foot disease.

Key words: three-phase bone scintigraphy (TPBS), arterial obstructive foot disease, amputation

INTRODUCTION

Aside from amputation of the lower limb, treatment options for arterial obstructive foot disease are limited because of the need to avoid the spread of infection, which can potentially invade the entire body. The level selected for amputation should generally be the lowest level compatible with tissue viability and involve a reasonable expectation of wound healing.[1] Retention of the knee joint by avoiding above-knee amputation would be extremely beneficial in the rehabilitation of patients and in improving their functioning in everyday life,[2,3] particularly for those patients who may need to have both lower limbs amputated.[4] Nevertheless, patients with arterial obstructive leg and foot disease are also at high intraoperative risk of coronary or cerebral artery obstruction, which necessitates that any surgery be confined to a single occasion in order to prevent reamputation. Therefore, determining the amputation level of an ischemic lower limb poses a difficult problem.

The findings of angiography or pulsation of the affected limb have no bearing on the success or failure of surgery.[1,2,4–9] In order to determine the most appropriate level of amputation, it is necessary to establish the extent of edema[9] and necrosis, the state of inflammation and infection, the degree of skin and soft tissue perfusion, and the viability of the affected limb.[1,2] The general consensus

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Table 1 Radioactivity and time after the radionuclide injection

case	Tc-99m-HMDP [MBq]	arterial phase [sec]	capillary phase [sec]	blood pool phase [min]	bone phase [hr]
1	1020	0–20	20–40	10	3
2	1036	0–40	40–80	10	3
3	938	0–30	90–120	10	3

is that a decisive and final decision should be based on the extent of the hemorrhage from the incised skin and soft tissue, and the suspected viability in the stump.[1–5,7,10] The latter judgment is often subjective, and therefore carries the risk that the method of surgery will differ from that anticipated.

In an attempt to determine whether the amputation level could be assessed more objectively in the preoperative period, the author applied three-phase bone scintigraphy (TPBS) to depict blood flow and viability of the skin and soft tissue.

MATERIALS AND METHOD

The cases of three patients who were to undergo amputation of the lower limb due to arterial obstructive leg and foot disease are reported. They were retrospectively selected from the medical record based on the findings of TPBS, the clinical examination and the comparison of the intraoperative and postoperative clinical states.

Following a bolus injection of Tc-99m-HMDP (Clear Bone® Kit) (radioactivity shown in Table 1), serial images of the legs were obtained with a two-head gamma camera (Starcam 4000i Maxxus, GE). TPBS images were acquired under the following three conditions.

Blood flow phase. Two divisions of the blood flow phase are shown: the "arterial phase" followed by the "capillary phase."[11] The arterial phase is indicated for the first 20–40 seconds after the radionuclide injection until there is an inflow from the trunk arteries to the small arteries and capillary vessels. The capillary phase is then indicated for between 20–120 seconds after injection (specification: Table 1). The arterial phase image and capillary phase image were made by addition through the arterial phase and the capillary phase, respectively.[11]

Blood pool phase. The blood pool phase was examined 5 and 10 minutes after the radionuclide injection. Imaging at 10 minutes was clearer than that at 5 minutes in patients with arterial obstructive leg and foot disease.

Bone phase. The bone phase was imaged 3 hours after the radionuclide injection.

CASE REPORTS

Case 1

A 57-year-old man with ASO (arteriosclerosis obliterans), who had been on hemodialysis for 16 years, presented with gangrene of the left heel and forefoot region.

Preoperative TPBS showed reduced radionuclide accumulation even in the arterial phase in his left leg, and three areas with decreased accumulation in the capillary phase and blood pool phase; the heel and forefoot region (Fig. 1D, red arrow), and the leg region (Fig. 2D, blue arrow). The decreased accumulation in the heel and forefoot region corresponded to the clinical findings of a necrotic region (Fig. 1, red arrow). There was no coincidence of necrosis with the decreased accumulation in the epidermis of his leg, although edema had been identified at the clinical examination (Fig. 2, blue arrow). Accumulation in the muscles during the capillary phase and blood pool phase had been maintained as normal, and no osteomyelitis or similar disease was detectable even on the bone phase. As a result, a below-knee amputation was performed. Surgical findings revealed severe edema in the epidermis of the leg and minor hemorrhage in the incised skin, but no evidence of necrotic tissue.

Skin necrosis occurred shortly after surgery and was identifiable as areas of decreased radionuclide accumulation in the capillary phase, but the muscles in the stump maintained a good color, although the condition of the stump as a whole was poor after one month (Fig. 3).

Case 2

A 48-year-old man with diabetes, who had been on hemodialysis for 14 years, manifested gangrene of his right foot (Fig. 4A).

In the arterial phase, the image of the trunk artery was suspended at the popliteal portion (Fig. 4B), but accumulation in the capillary phase and blood pool phase was fairly good in the entire leg (Fig. 4C, D). These findings suggested adequate perfusion and viability of the skin and muscles. TPBS showed no areas of focally increased accumulation in any of the three phases (Fig. 4C, D, E), implying that there was no inflammation or infection of the skin, soft tissue or bone.[12]

As TPBS findings in the arterial phase had indicated, obstruction of the trunk artery in the popliteal region was observed during the operation. The skin, muscle and bone when incised hemorrhaged smoothly during the operation. The patient had recovered well after two weeks and the stump continued to heal well after one month (Fig. 4F).

Rehabilitation was completed with a patella tendon bearing (PTB) below-knee prosthesis, affording good weight-bearing capability and the patient's gait was satisfactory.

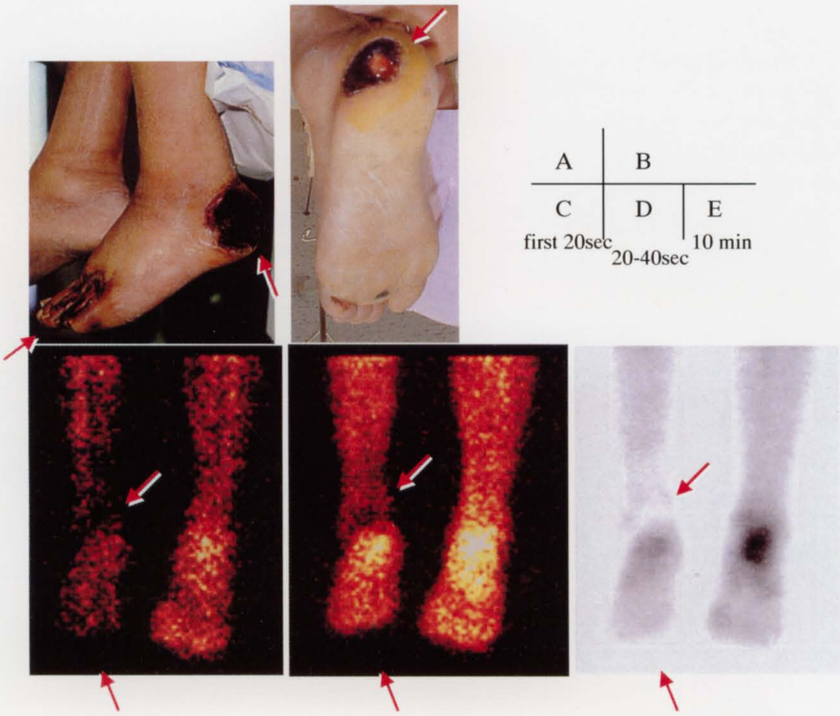

Fig. 1 [Case 1] A 57-year-old man with ASO, who had been on hemodialysis for 16 years. A, B: Gangrene of the left heel and forefoot. C, D, E: Posterior scan of TPBS. C: Arterial phase image. D: Capillary phase image. E: Blood pool phase image. Red arrows refer to decreased accumulation areas in D and E that coincide with gangrenous areas in A and B.

Fig. 2 [Case 1] A, B: Severe edema of the left leg (blue arrows). C, D, E: Anterior scan of TPBS. C: Arterial phase image. D: Capillary phase image. E: Blood pool phase image. Blue arrows refer to decreased accumulation areas in D and E, which correspond to the edema seen in the leg in A and B.

Case 3

A 48-year-old man with diabetes, who had been on hemodialysis for 14 years, had gangrene of the left foot. Four months after the preliminary diagnosis was made, it also occurred in the other limb.

During the capillary and blood pool phases, decreased radionuclide accumulation was observed in the distal portion of the leg (Fig. 5D, E), a finding which was not surprising when compared with the data obtained four months earlier (Fig. 5F). This area of decreased accumulation implied poor perfusion of the soft tissue or muscle of the leg. The internal findings of the condition of the muscles and soft tissue were not recognized externally at previous preoperative clinical inspections. This case contrasted with that of case 1 because of the decreased accumulation occurring predominantly in the skin.

An above-knee amputation was recommended by the author because the extent of the poor perfusion and ulcer reached beyond the distal portion of the leg and approached the likely below-knee amputation level (Fig. 5; yellow line). The patient refused this recommendation, insisting instead on a below-knee amputation. The intraoperative findings were of muscle necrosis in the posterior section of the leg, as TPBS had visualized. There was no hemorrhaging.

Approximately three weeks after surgery, the stump became necrotic and infection occurred in the lower leg muscles (Fig. 6A). The stump continued to deteriorate. Skin necrosis was not externally observable, although it was present in the soft tissue and muscles as the capillary phase had indicated. Recovery was suspended even three months after the operation (Fig. 6B).

1 Mo after op.

Fig. 3 [Case 1] One month after amputation. While the muscles in the stump maintained a good color, the skin over the stump became necrotic. The necrotic skin was coincident with the areas of decreased accumulation in the capillary phase and blood pool phase of preoperative TPBS.

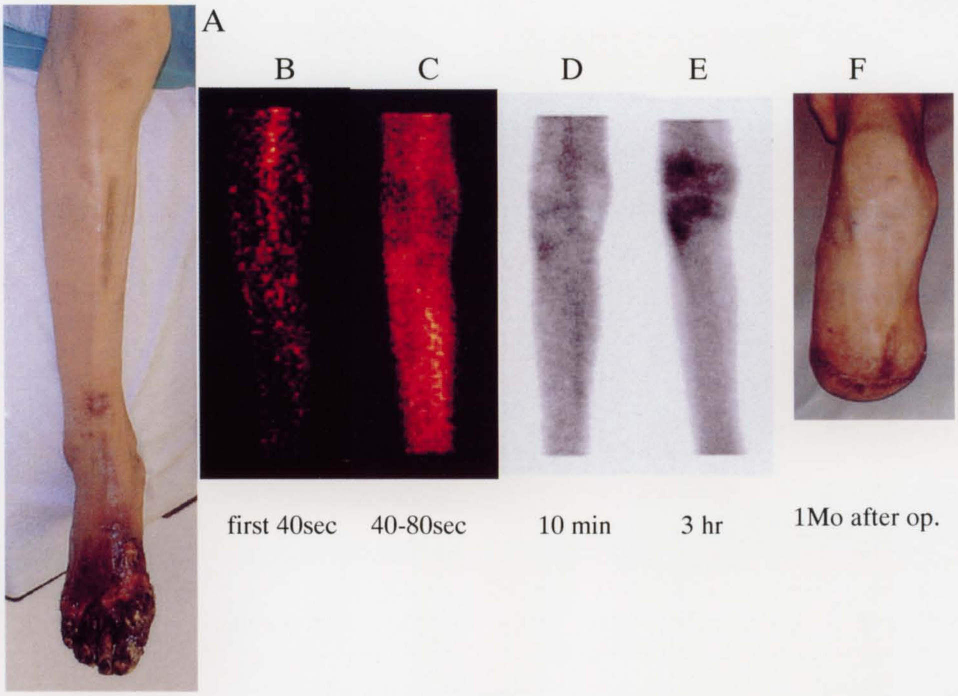

Fig. 4 [Case 1] A 48-year-old man with diabetes, who had been on hemodialysis for 14 years. A: Gangrene of the right foot. B: Arterial phase image. The image of the trunk artery was suspended at the popliteal portion. C: Capillary phase image. D: Blood pool phase. E: Bone phase. Decreased accumulation in the capillary and blood pool phases was essentially absent throughout the leg. F: One month after the operation. Healing of the stump was progressing well.

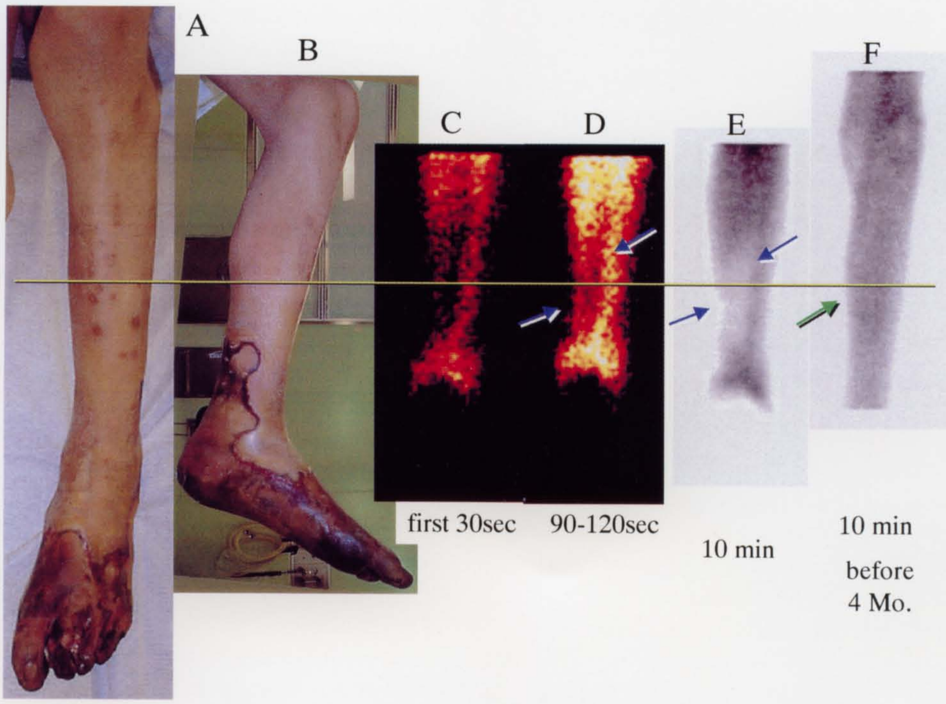

Fig. 5 [Case 3] A 48-year-old man with diabetes, was had been on hemodialysis for 14 years. A, B: Gangrene on his left foot. C: Arterial phase image. D: Capillary phase image. E: Blood pool phase. Decreased accumulation in the leg appeared in the capillary phase and blood pool phase. F: Blood pool phase of the same patient 4 months earlier. There had been no decreased accumulation.

Fig. 6 [Case 3] A: Three weeks after surgery. The soft tissue and muscles became necrotic and infection occurred in the stump, as the capillary phase indicated. However, skin necrosis was absent. B: Recovery was halted in less than three months postoperatively.

DISCUSSION

Patients with arterial obstructive foot disease frequently suffer with gangrene of the lower limbs. When conservative treatment does not proceed well, amputation is most likely necessary. The general principle employed in determining the amputation level is to perform amputation at the most distal level.[1,5] Retention of the knee joints by avoiding an above-knee amputation is desirable for promoting rehabilitation,[2,3] particularly for patients who may require both lower limbs to be amputated,[4] but since amputation should be completed on a single occasion to avoid potentially hazardous reamputation, determining the amputation level is a critical clinical decision.

The level at which to amputate the ischemic limb remains controversial, despite the number of predictive studies performed.[1,2,4,6,13,14] The findings of angiography or pulsation of the affected limb do not relate to the success or failure of amputation surgery,[1,2,4–9] because trunk arteries and palpable pulsations do not reflect collateral circulation, and in the ischemic limb the collateral circulation is the major determinant of wound healing.[2,4,7] The surgeon usually selects the actual amputation level during surgery, because the intraoperative observations of bleeding from the incised skin and the viability of soft tissue, especially muscle, in the stump[1–5,7,8,10] cannot be made preoperatively, and are therefore usually subjective.

Orthopedists have long wanted to base this difficult clinical decision on (1) preoperative, (2) objective, and (3) visual information of the affected areas. In patients with arterial obstructive foot disease, bleeding from the incised skin and soft tissue during the operation does not occur from the trunk arteries. Instead significant bleeding from the incised skin and soft tissue supposedly derives from the small arteries and capillary vessels. Consequently, a method that assesses this latter level of dysfunction should provide the orthopedic surgeon with the desired information.

Some studies have reported that an objective indicator of the healing potential of an ischemic ulcer is the assessment of hyperemia or blood flow around the lesion.[6,15] These studies also suggest that the likelihood for healing is reduced by low skin blood flow and perfusion, and that the actual state of skin or muscle perfusion should be evaluated in addition to angiography, by measuring the muscle blood flow in the leg,[16] estimating local perfusion pressure, and carrying out perfusion scanning with radioisotopes,[5] among other techniques.[17] Bone scanning, especially TPBS, has also been used in the evaluation of most vascular problems[18] including monitoring the blood supply[19] and viability of bone grafts[20] or of the femoral head after femoral neck fracture, and in the detection of soft-tissue lesions.[21] A few studies have reported that bone scanning is a reliable procedure for use when deciding the limb amputation level.[22–24] In the present study, the author applied TPBS to assess the blood flow in the small arteries and capillary vessels in an attempt to detect necrotic lesions,[23,24] and ultimately to determine the level of amputation.[21] The hypothesis was based on the notion that radionuclide accumulation in the capillary phase and blood pool phase of TPBS should indicate areas of the incised skin that could be expected to bleed intraoperatively. In addition, areas showing decreased accumulation should identify lowered focal viability[21,24] that subsequently shows gangrenous change.

In cases 1 and 3, the capillary phase depicted the perfusion of blood from the small arteries to the capillary vessels. Decreased accumulation in the capillary phase coincided with a lowered blood inflow from the small arteries to the capillary vessels. This decreased accumulation in the capillary phase appears as two distinctive states: one of clinically remarkable necrosis and the other of decreased blood flow in the small arteries and capillary vessels. The latter inevitably causes necrosis and infection postoperatively (Figs. 3, 6), even if it does not appear as necrosis preoperatively (Figs. 2, 5). In case 3, the middle portion of the leg, where decreased accumulation was detected in the capillary phase, showed muscle necrosis at the time of surgery, and conformed to the same area of more progressive necrosis and infection in the leg muscles postoperatively.

In case 2, on the other hand, there was no area of decreased accumulation in the capillary phase of the skin or soft tissue, and the whole lower-limb was, therefore, assumed to be viable. In addition, osteomyelitis was confirmed to be absent by the lack of focal accumulation in the bone phase. Cases such as this were assumed to show less risk of necrosis[5,20] and infection, and no deterioration of the stump.

It has been established that TPBS contributes to the detection of osteomyelitis even when it is not apparent on clinical inspection.[12,25] Accordingly, the author recommends that rather than ordering a plain bone scan or TPBS to detect only osteomyelitis prior to amputation, it would be more useful to carry out blood flow phase testing with arterial and capillary phases, because it provides important information about skin and soft tissue perfusion and viability. The author believes that TPBS of the entire leg can also provide data about the regional blood supply, which should enable a more objective preoperative decision about the amputation level to be made. TPBS can therefore assist the orthopedic surgeon in avoiding an intraoperative change in surgical procedure.

CONCLUSION

TPBS shows the blood flow in small arteries and capillary vessels, which indicates regional perfusion and viability of the skin and soft tissue as well as the presence of osteomyelitis. TPBS is likely to become a useful clinical tool to assist the orthopedist in making a more objective decision regarding the amputation level of ischemic lower limbs and the surgical procedure to be employed, prior to surgery.

NOTE

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