PRE-AMPUTATION DECISION-MAKING

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Despite modern revascularisation techniques and advances in the management of diabetes and peripheral arterial disease (PAD), amputation rates remain high. Diabetic vasculopathy is a significant contributor to limb loss. As the population's life expectancy continues to increase, the incidence of limb loss due to PAD is also increasing.

The contemporary vascular surgical approach to limb ischaemia is to attempt aggressive limb salvage in almost all patients. When successful, this is largely due to advances in revascularisation, with most advances seen in the endovascular arena.

The rationale for limb salvage is that more adverse outcomes are seen in amputees. If amputation cannot be avoided, as much tissue as possible should be preserved. Thus digit amputation should be considered before ray amputation, trans-metatarsal before below knee amputation (BKA), BKA before above knee amputation (AKA), and AKA before hip disarticulation. Lower level amputations allow better functional outcomes of the amputees, with less energy expenditure and greater ability to ambulate and regain independent living. The more tissue that remains, the more likely the patient is to successfully ambulate using a prosthesis.

The energy expenditure of walking is inversely proportional to length of the remaining limb. A BKA conveys an extra metabolic demand of 10% (for a long stump) to 40% (for a short stump) above baseline. Patients with through knee amputations or AKA expend an additional 65% or 72% respectively.
The highest energy expenditure is after hip disarticulation, reaching 82% above baseline. The rate of ambulation post-amputation is 80% for BKA, 31% for through knee amputation, 38-50% for AKA, and 0-10% for hip disarticulation.

The ability to regain functional independence is negligible after major amputation (including AKA). Only 10-25% of patients post-BKA will regain functional independence.

Table 1. Energy expenditure and ambulation rates.

<table>
<thead>
<tr>
<th>Amputation level</th>
<th>Energy expenditure</th>
<th>Ambulation rate</th>
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<tbody>
<tr>
<td>BKA: Long</td>
<td>10%</td>
<td>80%</td>
</tr>
<tr>
<td>Short</td>
<td>40%</td>
<td></td>
</tr>
<tr>
<td>Through knee</td>
<td>71.5%</td>
<td>31%</td>
</tr>
<tr>
<td>AKA</td>
<td>65 (50-70)%</td>
<td>38-50%</td>
</tr>
<tr>
<td>Hip disarticulation</td>
<td>82%</td>
<td>0-10%</td>
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The goals of amputation are:
- To remove all infected and necrotic tissue and thus allow wound healing.
- To create a functional stump that can accommodate a prosthesis or aid in ambulation.

INDICATIONS FOR AMPUTATION

Ischaemia
- Acute: irreversible ischaemia that is unsuitable for revascularisation or failed revascularisation.
- Chronic: extensive sepsis, failed revascularisation, or extensive gangrene with lack of target vessels or outflow.

Infection
- Pedal sepsis without features of ischaemia. This is common in patients with complicated or poorly controlled diabetes.
Trauma

- Mangled limb, taking into consideration the skeletal and soft tissue injury, warm ischaemic time, age of patient, neurovascular injury, pre-existing disease, and presence of shock. Mangled Extremity Severity Score (MESS) of seven or greater is predictive of amputation.

Malignancy

- In patients where limb salvage is not possible.

CONFOUNDING FACTORS

Diabetes Mellitus (DM)

DM, alone or in combination with ischaemia, accounts for a significant number of amputations. 60-80% of patients needing amputation have DM. Of these, 15-25% have soft tissue infections without ischaemia, 3-5% have chronic osteomyelitis, and 5-10% have ischaemia without infection. DM causes hemodynamic, neurohumoral and metabolic changes; with resultant endothelial dysfunction and intima media changes. There is also medial impairment of the fibrinolytic system and platelet function. The likelihood of limb loss is very high, especially with delayed interventions.

Other co-morbidities

Patients with other significant comorbidities, obesity and/or advanced age are often unable to regain bipedal gait. Those with poor balance due to previous stroke, neuropathy, or artificial joints are also unlikely to walk independently post-amputation. Patients with poor nutrition or skin changes due to oedema or venous stasis often experience delayed wound healing.

Although aggressive limb salvage is the modern approach to limb ischaemia, there is subgroup of patients that may be better served with primary amputation or non-operative management. The group includes patients with advanced diabetes mellitus disease complications, end stage renal disease, extensive tissue loss, and poor functional status.
Most of these patients have poor baseline functional status and have already lost the ability to ambulate and live independently. The pro-inflammatory state destabilises atherosclerotic plaques by generating reactive oxygen species and thus increases patients' risk for myocardial infarction or cerebral ischaemic event. Aggressive risk factor modification, including use of antiplatelet agents and statins, has improved outcomes in this population of patients.

**Sepsis**

Tissue sepsis often makes deciding on the appropriate amputation level difficult. Sepsis may further compromise stump healing, even with systemic antibiotics. Guillotine amputation for initial source control, followed by formal stump closure a few days later, has lower complication rates than single stage amputation.

**Delay in presentation**

The reported mean time to vascular consultation in first world countries is 73 days for pedal tissue loss and 27 days for ischaemic rest pain. The delay may be due to patient and/or system factors. Our patients generally present much later, often with extensive disease. The paucity of vascular services and thus length of waiting periods for patients to see a vascular surgeon, further exacerbates the problem.

**PRE-OPERATIVE EVALUATION**

**Systemic**

- Comorbidities.
- Mental/ neurological function.
- Ambulatory status.
- Life expectancy.
Regional

- Duration and severity of ischaemia.
- Extent of tissue loss.
- Presence of wound infections.
- Anatomic considerations for revascularisation.

OBJECTIVE AND CLINICAL TESTS

Most tests assess prediction of healing, not failure. Failure of amputation to heal is not uncommon, mostly due to haematoma formation, infection, trauma, ischaemia, and technical issues. There is a high incidence of re-intervention/revision, with conversion from BKA to AKA being necessary in 15-25% of patients.

It is very important to assess the patient adequately and thus optimise successful surgery and good functional outcome.

Physical examination

Assessment includes evaluation of the extent of gangrene and infection. Skin temperature is highly subjective but may have significant accuracy in experienced clinicians. Palpable pulses proximal to the proposed amputation level has a positive predictive value of almost 100% for stump healing; however a non-palpable pulse does not necessarily predict failure.

Haemodynamic tests

- Non-invasive
  - Ankle blood pressure (BP): measurement of 60mmHg predicts healing of BKA with an accuracy of 50-90%. It is unreliable in patients with medial calcinosis, as in DM.
  - Ankle Brachial Index (ABI): if greater than 0.5 the reported failure rate at 6-12 months is 10-15%; whilst if less than 0.5 the reported failure rate is 28-34%.
• Toe pressure (TBP): measurement of 30mmHg predicts forefoot healing. TBP maintains its accuracy even in non-compressible vessels. Its usability is limited by the presence of forefoot ulcerations or tissue loss.

• Transcutaneous O$_2$ measurement: a small sensor is placed in the area of interest. Sensor and skin are heated to 44°C, resulting in local hyperaemia and arterialisation of capillary flow. Reading of more than 40mmHg predicts healing, and less than 20mmHg predicts failure. It requires simple instrumentation, is easy to measure, and is highly reproducible. It is artificially low in infection, inflammation, and edema. It is more accurate than segmental pressure measurement, skin blood flow measurement, and fluorescein dye injection technique.

• Skin perfusion pressure (SPP): measures pressure at which the flow ceases in the capillary system. Measurement is done through laser Doppler, radioisotope clearance, or photoplethysmography.

• By slowly decreasing cuff pressure at the site of measurement, reappearance of pulsatile flow, movement of red blood cells, or washout of isotope is detected. SPP of greater than 40mmHg predicts healing in more than 90% of patients, and SPP of less than 20mmHg predicts failure in 89% of patients.

### Table 2. Summary of predictive tests for wound healing.

<table>
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<tr>
<th>Test</th>
<th>Threshold</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
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<tbody>
<tr>
<td>SPP</td>
<td>40</td>
<td>72</td>
<td>88</td>
</tr>
<tr>
<td>Tc PO2</td>
<td>30</td>
<td>60</td>
<td>87</td>
</tr>
<tr>
<td>TBP</td>
<td>30</td>
<td>63</td>
<td>90</td>
</tr>
<tr>
<td>ABP</td>
<td>80</td>
<td>74</td>
<td>70</td>
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• Invasive

These are physiological tests that estimate the level of perfusion or oxygen delivery at tissue level and thus predict likelihood of healing.

• Arteriography: invasive, costly, with poor correlation between arterial patency and wound healing. It is not recommended as a means of prediction of stump healing.
• Intradermal isotope: Iodine-125 or Xenon-133 is injected intradermally and the washout rate or clearance is determined using scanning devices. There are conflicting reports regarding reliability of its use.
• Technicium-99 Sestamibi scan: able to assess deep tissue perfusion, thereby being able to determine the level of amputation. Though cumbersome, it seems reliable.
• Skin fluorescence: intravenous fluorescein dye is injected and uptake analysed using ultraviolet light. It is falsely positive with inflammation and infection.

SUMMARY
Most of the above-mentioned investigations used to assess distal limb perfusion are not readily available. Good clinical judgment in combination with accessible investigations should be used when assessing a limb for possible amputation. Extremity wound healing, technical considerations, and need for optimisation of comorbidities must be included in the decision making process.

REFERENCES


