Management of lower limb amputations

Despite differing reasons for lower limb amputations, there are consistent surgical and prosthetic principles which can offer improved functional outcomes, so that prosthetic fitting, mobility and quality of life can be optimized in a meaningful, appropriate way for the individual.

ABSTRACT

The most common reason for lower limb amputations in the UK is peripheral arterial disease. A thoughtful approach to surgery, with consideration of optimal amputation level and residual limb shape, can improve prosthetic use and functional outcomes. Prosthesis socket design and fit, as well as use of appropriate components, must be considered in accordance with the patient's activity level and potential. Major developments in prosthetics over the past 20 years, particularly in the area of joint design, including microprocessor knees, have increased options to improve ambulation. This is particularly significant among those with more proximal amputations, for whom energy expenditure on walking is even greater. Management of post-amputation pain syndromes including phantom limb pain can prove challenging, although there are novel options for pain control. Long-term care of both the residual and contralateral limbs is paramount to reduce risk of further amputation surgery, and optimize longer term function and quality of life.

Reasons for amputation

Over 11 500 major lower limb amputations are performed in the UK each year (All-Party Parliamentary Group on Vascular Disease, 2016). The average age for people having a lower limb amputation is 70 years, with men outnumbering women by 3:1. Most lower limb amputations are secondary to acquired conditions leading to vascular disease, and these patients have an average 22-day hospital stay following amputation (National Vascular Registry (UK), 2016). Peripheral arterial disease affects about 20% of those aged 60 years and over. Those with peripheral arterial disease are also more likely to have other comorbidities, conferring poorer functional outcomes and higher mortality rates (Kristensen et al, 2012). For patients with peripheral arterial disease, smoking, diabetes mellitus and coronary artery disease all increase the risk of requiring an amputation. The risk of lower limb amputation in those with diabetes is over 20 times greater than that of the general population, and about 7000 patients with diabetes undergo lower limb amputations in England each year (NHS Digital, 2017). As 3.8 million people in England aged over 16 years have diabetes, the risk of lower limb amputation among this group is significant (Public Health England, 2016).

The National Institute for Health and Care Excellence (2012) guidelines recommend that for those with peripheral arterial disease, major amputations should only be offered to those with critical limb ischaemia after all avenues for vascular revascularization have been exhausted (Layden et al, 2012). Revascularization must be achieved within 6 hours to prevent irreversible muscle damage, so major amputation rates remain at 10–30% (Abdulhannan et al, 2012).

Amputations still confer a high risk of mortality (up to 48% at 1 year post major limb amputation), so a broader understanding of perioperative, preoperative and postoperative management is useful (National Confidential Enquiry into Patient Outcome and Death, 2014).

While the high risk of mortality reflects the population group most at risk of amputation, traumatic limb amputees are also at increased risk of cardiovascular disease, which shares a parallel relationship with peripheral arterial disease (Naschitz and Lenger, 2008; Brevetti et al, 2009).

Amputations can also be necessary in circumstances other than peripheral arterial disease. In the UK, trauma and malignancy are the cause of 10% and 3% of lower limb amputations respectively, and a further 1.7% had a congenital limb deficiency. Of the latter, about half will be a congenital limb anomaly, including complete or partial absence of a long bone, which is not conducive to enabling functional mobility, therefore requires amputation (United National Institute for Prosthetics & Orthotics Development, 2015).

Amputation level and implications for prosthesis

In 2014, the International Organization for Standardization introduced new terminology to describe amputation levels. The terms 'below' and 'above knee' have been replaced with transtibial and transfemoral respectively (*Table 1*). The limb stump is referred to as the residual limb and the 'good' or 'sound' limb referred to as the contralateral limb (International Organization for Standardization, 2014).

In England, for the period 2003–2013, there were 22 645 transfemoral, 19 658 transtibial and 52 525 minor amputations (i.e. below the ankle) (Ahmad et al, 2016). In adults, the more proximal the amputation, the greater the difficulty in both fitting and suspending a prosthesis and also the greater the energy expenditure when mobilizing, particularly when the knee joint has not been preserved.

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Table 1. Classification of amputation levels

Previous or common terminology	International Organization for Standardization terminology
Transmetatarsal	Partial foot
Syme's (through ankle)	Ankle disarticulation
Below knee	Transtibial
Through knee	Knee disarticulation
Above knee	Transfemoral
Through hip	Hip disarticulation
Hemipelvectomy	Hemipelvectomy

from International Organization for Standardization (2014)

However, preservation of length must be balanced against aetiology, e.g. amputation to manage sarcoma has to prioritize excision and removal of malignancy, amputation to manage osteomyelitis has to prioritize infected bone tissue and amputation to manage vascular disease has to prioritize the ischaemic limb. The transtibial level is thought to be the highest level of lower limb amputation that has the potential to restore near-normal function.

Guillotine amputation reduces the likelihood of creating a prosthesis-appropriate residual limb, so is discouraged where good functional outcome is likely. Among those for whom functional prosthetic use is possible, amputation surgery aims to optimize a functional, weight-bearing residual limb. Amputation level and shape of the residual limb impact on rehabilitation, and prosthetic fit and comfort.

Amputation should be distinguished from disarticulation. In the latter, no bone or muscle is dissected. Disarticulation can offer better preservation of muscle and better end weight bearing of a prosthesis, which is important in providing better fit for and control of a prosthetic. The main disadvantage is the reduced space available for prosthetic components compared to amputations. Disarticulations are generally preferable in children as an amputated bone end tends to over grow, necessitating surgical trimmings until skeletal maturity is reached (Kobayashi et al, 2013).

Amputation levels and options for prostheses

Toe and partial foot amputations

Partial toe amputations allow good mobility, although sufficient base support length is required for adequate skin flaps to enable wound closure and healing. Preserving the soft tissue pad to the first and fifth toes protects the metatarsal head. Toe amputations may not always require use of a prosthesis, and an orthosis may offer improved ambulation.

Metatarsophalangeal joint disarticulation offers an alternative to partial toe amputation, and preserves the metatarsal head. As with other disarticulations, blood loss and healing time are reduced.

Partial foot amputations are often performed as a limb-sparing procedure, particularly where there is localized necrosis and/or infection. Amputations at this level are offered to mobile patients able to benefit from increased energy preservation compared to more proximal level amputations. Partial foot amputations may take the form of a ray (excision of the toe and all or part of the metatarsal) resection. Transmetatarsal amputations can be divided into disarticulation at the tarsometatarsal and transtarsal joints (amputation at the level of the transcalcaneus), or amputation through the metatarsal bones.

Tarsometatarsal (Lisfranc's) and transtarsal (Chopart's) disarticulations are mid and hindfoot amputations respectively. They are best avoided in patients with diabetes-related infected ulcers, because of the risk of infection advancing to the heel pad.

Transtarsal or Boyd's amputation occurs in the forefoot, through the talonavicular and calcaneocuboid joints, i.e. at the level of the ankle, preserving the calcaneus and heel pad.

More proximal partial foot amputations are associated with increased ankle muscle imbalance and tendency for plantarflexion, as ankle plantar flexors in the calf are preserved while the ankle main and accessory dorsiflexors are lost. A plantarflexed ankle results in excessive forces affecting the end of the amputation stump, causing pain and scar breakdown. The prosthetic solutions for partial foot amputations are limited. An ankle foot orthosis may be used to correct the ankle position, but the cosmetic outcome is usually poor and the orthosis limits shoe choice. The functional outcome with a partial foot prosthesis might often be less favourable than an ankle disarticulation.

Ankle disarticulation

Syme's or ankle disarticulation by preserving the heel pad is useful for conditions affecting the foot and ankle. It allows end weight bearing, and therefore easier fitting of a prosthesis. As with foot amputations, patients who have undergone ankle disarticulation are able to walk on the residual limb without a prosthesis, e.g. when mobilizing short distances at home. However, amputations at the foot all confer the risk of equinovarus deformity as a result of unopposed action of the Achilles tendon (Nather and Wong, 2013).

Transtibial amputation

Amputations at the transtibial level are the most common (United National Institute for Prosthetics & Orthotics Development, 2015), reflecting peripheral arterial disease as the main precipitant, since salvage of the distal limb is incompatible with symptom control. Amputation at the transtibial level has to allow sufficient soft tissue and muscle coverage, so that a prosthesis can be fitted, without risking skin breakdown in the distal stump (Robinson, 1991).

The transtibial level is thought to be the highest level of lower limb amputation that has the potential to restore near normal function. The prosthetic socket is designed to transfer weight through the patellar tendon, enabling a good range of movement in the knee.

Knee disarticulation

Knee disarticulation preserves the thigh muscles, and preservation of cartilage offers improved resistance to infection, which helps wound healing as well as improving end weight bearing. This tends to offset the drawback of a bulbous residual limb, which can complicate prosthetic fit at the initial stage. However, the bulbosity becomes useful for suspending the prosthesis once the initial oedema resolves. There is ongoing debate regarding the benefits of retaining the patella in this level of amputation, and the authors' preference is to remove the patella to avoid possible fitting complications in case it detaches as a result of quadriceps muscle pull, making it free floating and painful.

Transtibial residual limb shape and length

A cylindrical residual limb shape offers better prosthetic suspension. The residual limb length is optimized so as to not be too long that soft tissue coverage is insufficient, or too short so that prosthesis use is impossible. Generally, the length of a transtibial residual limb should be 10 cm for every metre of the person's height, or 1 inch for every foot of height, measured from the medial aspect of the tibial plateau to the cut end of the tibia. The shortest length that could be practically fitted with a prosthesis within current technology is 8 cm (Al-Fakih et al, 2016).

Transfemoral amputation

Transfemoral amputations confer increased metabolic expenditure when ambulating, and are often associated with worse functional outcomes. Approximately 60% of these patients are too frail to safely use a prosthesis (Steward and Trimmings, 2008). For those able to manage a prosthesis, weight bearing is transmitted from the socket to the ischial tuberosity, which forces the design of the socket to be tight around the groin area. This tends to cause discomfort, especially with changes to prosthetic fit, and generally interferes with toileting (Gottschalk and Stills, 1994).

Hip disarticulation and hemipelvic amputations

Hip disarticulation and hemipelvic amputations are rare in the UK and usually secondary to malignancy. Walking with a prosthesis at these levels requires more energy and is slower compared to hopping on crutches, resulting in a high prosthesis rejection rate. The main indication for prosthetic provision is to reduce lower back pain, and wear and tear in the shoulders (Meier and Melton, 2014).

Prosthetic prescription considerations

Integral constituents of the prosthetic prescription include socket, interface, suspension, pylon, foot/ankle and joint unit. The prosthetic prescription is dictated by the user's activity level.

The socket must be comfortable and secure, accommodating the weight-bearing area, which is dependent on the level of amputation and shape of the residual limb. The socket design should avoid surplus contact over bony areas, on which weight bearing is inadequate and painful. Liners are generally worn over the residual limb, forming an interface between it and the socket. These liners are predominantly gel, silicon or polyurethane. The prosthesis is held at the residual limb by suspension – good suspension minimizes movement between the residual limb and the socket, improves proprioception and reduces the energy requirements for walking.

Generally, more active limb users benefit from suction or vacuum suspension, which also improves proprioception. Other liner types use a pin-lock mechanism, where a screw-type fitting secures the liner to the socket. Pin-lock systems are practical and suitable in the absence of distal stump pain. Less active users may opt for suspension comprising lanyards, cuff straps or belts (Al-Fakih et al, 2016).

Hip disarticulations and hemipelvectomy (loss of the ilium, ischium and pubis) mean that the hip, knee and ankle joints have to be replaced within the prosthetic limb, making control and stabilization of the prosthesis difficult when walking. Technical advances, especially in the design of joints, offer prosthetic options with improved stability by using multi-centric joints and/or microprocessors; these are crucial in enhancement of prosthetic knees. Microprocessor controlled knees have been available since the 1990s and transformed the potential for ambulation among those with transfemoral amputations. These have a microprocessor (a small programmable computer) within the knee unit. This receives input from sensors that continuously analyse the user's gait. As microprocessor controlled knees use real-time information based on the user's gait to vary the knee resistance, the risk of falls and energy requirements for walking are reduced. The computer controls knee joint resistance, making it softer for improved swing and stiffer during stance or when stumbling, minimizing the risk of falls. Microprocessor controlled knees have been available in the NHS since December 2016, and are only offered to selected patients who are already able to manage ambulation with a conventional free mechanical knee (NHS England, 2016).

Osseointegration, first developed within dentistry in the 1960s, has been used since the 1990s among patients encountering insurmountable difficulties with their residual limb and socket, e.g. shape and length of residual limb. An intermedullary titanium plate is inserted into the residual limb which can be attached directly to the prosthesis without the need for a socket. The surgery is reserved for select patients and complications include infection and peri-prosthetic fracture (Kaulback and Jones, 2017).

Post-amputation management

Appropriate rehabilitation for those with limb loss improves prosthetic use and mobility. This includes older people with a good level of pre-morbid independence (van Eijk et al, 2012).

With provision of adequate analgesia, physiotherapy input can begin on the first day postoperatively in the absence of complications. Using a compression sock on the residual limb alleviates postoperative swelling and shapes the limb ready for prosthetic use. The most commonly used postoperative walking aid in the UK is the Pneumatic

Post-Amputation Mobility aid (Ortho Europe). This can be used for those with transtibial or transfemoral amputations, where there is a long residual limb. Early use of walking aids further reduces swelling and promotes wound healing. The Pneumatic Post-Amputation Mobility aid is partial weight bearing. It is not a temporary prosthesis and is only used during physiotherapy sessions. The Pneumatic Post-Amputation Mobility aid offers physical and psychological preparation for prosthesis use. It can be used at 4 days postoperatively in patients with traumatic amputations, or from 6 days postoperatively in those with amputations secondary to dysvascularity. Patients are educated in fall prevention and management strategies. A wheelchair is still provided, as the risk of falls among lower limb amputees is greater, particularly the more proximal the amputation level (Broomhead et al, 2006). A patient is regarded as established at 1 year post amputation, although this will not mean resolution of all post-amputation complications.

Care of the residual limb extends beyond postoperative wound management. Ongoing skin care is essential, as prosthetic use increases friction and moisture. This affects prosthesis fit and can increase risk of skin infections with potentially catastrophic ramifications, including sepsis or need for further surgery. Residual limb skin care is paramount including appropriate hygiene and daily use of emollient.

Care of the contralateral limb is vital. It is at increased risk of osteoarthritis and, in patients with diabetic neuropathy, there is ongoing risk of injury to the contralateral foot. This can be exacerbated by gait abnormalities which can also precipitate back pain. Patients may have difficulty adjusting to the loss of a limb, and psychological support should be available (Kulkarni, 2008).

Phantom limb complex

Phantom limb pain forms part of a complex which also includes phantom limb sensation. Phantom limb sensation is painless, while phantom limb pain is always uncomfortable. Phantom limb pain is reported postoperatively by 60–85% of amputees, with variable intensity and frequency (Hanyu-Deutmeyer and Dulebohn, 2017). Since pain can be a pre-amputation prodrome, preoperative amputation pain can increase the risk of phantom limb pain as a result of sustained nocioceptive input, but even in traumatic amputations of a healthy limb there is a risk of post-amputation pain. Optimal preoperative pain management is necessary. Pre-emptive analgesia, including during the intraoperative period, helps reduce chronic post-amputation pain (Srivastava, 2017). The pathophysiology is not fully understood, although it is believed to involve both peripheral and central mechanisms, with abnormal evoked activity and cortical reorganization respectively (Subedi and Grossberg, 2011). While most patients experience phantom limb pain soon after surgery, it can occur several years later. The mainstay of treatment is pharmacological, surgical (e.g. sympathectomy or implanted spinal cord stimulators), and other non-pharmalogical adjunctive therapies, including transcutaneous electrical nerve stimulation and graded motor imagery. The latter uses left–right discrimination, explicit motor imagery (imagined movement) and mirror therapy to help ameliorate pain. It is cost-effective and non-invasive, and encourages a proactive approach to pain management, which some patients find helpful (Limakatso et al, 2016).

Pharmacological treatments have much in common with analgesia used in other chronic pain syndromes, including tricyclic antidepressants, anticonvulsants and benzodiazepines. Calcitonin infusions have been found to be useful, although side effects, including hot and cold flushes, and nausea, often prevent their use (Alviar et al, 2016). As N-methyl D-aspartate (NMDA) receptors play a role in central induction and maintenance of pain, NMDA antagonists, including ketamine and memantine, can offer pain relief, although side effects (e.g. hallucinations) can make their use impractical (Nikolajsen and Jensen, 2001).

An electromagnetic shield within the residual limb liner may offer relief from phantom limb pain (Fisher et al, 2016). This is useful for those reluctant to use pharmacological treatment, or who experience side effects with oral analgesia.

Residual limb pain can be secondary to other underlying pathologies, e.g. peripheral arterial disease, skin infections, nerve entrapment and neuroma, so these must be excluded before phantom limb pain is diagnosed. A neuroma is scar tissue at the end of a severed nerve and is almost always present post-amputation, although not always associated with pain. Pain occurs with an increase in sodium channels and subsequent increase in nerve excitability (Alviar et al, 2016). Whether neuromas are the cause of residual limb pain can be assessed by stimulating the neuroma and seeing whether this evokes a pain response corresponding to the patient's description. A painful neuroma can trigger secondary phantom limb pain, which usually improves once the neuroma is treated. Where this assessment is equivocal magnetic resonance imaging can be useful, although findings must be reviewed within the clinical context, correlating findings with the history and examination. Treatments for neuromas include percussion, local anaesthetic, nerve ablation and neurolysis. Some patients may opt for surgery, although the risk of recurrence persists (Zhang et al, 2017).

Phantom limb sensation, which may or may not be associated with phantom limb pain, is experienced by most amputees, associated with the sensation of persistent presence of the absent limb. It can occur spontaneously or via evoked sensory input. Some patients may also experience telescoping, when the distal part of the phantom limb is felt to be close to or within the residual limb (Alviar et al, 2016).

As with other chronic pain syndromes, pain is multi-factorial and psychological states can exacerbate pain, so these should be considered when counselling patients with regards to pain management, and psychologically-based treatment may also play a role.

Conclusions

Despite advances in approaches to revascularization, lower limb amputations among those with dysvascularity remain prevalent. Regardless of aetiology, a considered approach

KEY POINTS

- Dysvascularity, which is more prevalent in an ageing population, is the leading cause of lower limb amputations in the UK.
- The increasing incidence of diabetes will result in greater number of patients at risk of lower limb amputation.
- Lower limb amputations confer an increased mortality risk.
- Energy expenditure when walking increases the more proximal the amputation.
- Advances in prosthetics, particularly microprocessor knees, can improve the ambulation potential of transfemoral amputees.
- Appropriate surgical fashioning of the residual limb combined with a well-made prosthetic socket increase success for prosthetic users.
- Phantom limb complex includes phantom limb pain and phantom limb sensation. The management of phantom limb pain can be pharmacological, non-pharmacological or a combination of both.
- Other causes of pain, including infection, neuroma or recurrence of precipitating condition, must be excluded when treating phantom limb pain.

to amputation and post-amputation rehabilitation, in conjunction with appropriate prosthetic prescription, can support patients in achieving improved mobility. Risk of post-amputation complications can be improved with careful attention paid to fashioning the residual limb, regular fitting checks and patient education regarding long-term skin management. Phantom limb complex, although likely to affect most amputees to some degree, can be managed in the preoperative, intraoperative and postoperative period, with a holistic approach to pain management including pharmacological and adjunctive therapies. **BJHM**

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