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Modified Gritti–Stokes amputation: tips and tricks

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- Major amputations of the lower extremity may be required after trauma and a variety of underlying diseases such as peripheral vascular disease, diabetes, and malignancies.
- The goal of any major amputation is an optimal functional result with a maximum limb length in combination with optimal wound healing. The preservation of the knee joint is essential for successful rehabilitation, and this is best achieved by the Burgess below-knee amputation (BKA).
- Whenever a BKA is not possible, the Gritti–Stokes amputation is our first choice.
- This technique mainly consists of a through-knee amputation with the creation of a pedicled patella flap consisting of the patella, patellar ligament, and overlying soft tissue. After osteotomy of the distal femur and resection of the articular surface of the patella, the anterior flap is rotated in order to cover the femur defect while performing a patellofemoral arthrodesis.
- The aim of this paper is to describe our surgical technique and experience with GSA and to point out the important steps of this procedure.
- In conclusion, GSA is an excellent surgical option for patients requiring major lower limb amputations where BKA cannot be considered. Particular attention must be paid to careful preoperative evaluation and optimization of comorbidities. A meticulous surgical technique is warranted, including atraumatic tissue handling and an optimal patellofemoral arthrodesis technique.

Keywords: amputation; lower limb; Gritti–Stokes; trans-knee amputation

Introduction

Major amputations of the lower extremity may be required after trauma and variety of underlying diseases such as peripheral vascular disease (PVD), diabetes, and malignancies. The goal of any major amputation is an optimal functional result with a maximum limb length in combination with optimal wound healing to avoid multiple reoperations and prolonged hospitalization.

The preservation of the knee joint is essential for successful rehabilitation in the elderly and cannot be overemphasized. This is best achieved by the Burgess below-knee amputation (BKA), which has been shown to result in successful healing in >85% of properly selected patients (1). However, this amputation technique requires a distal pattern of ischemia with an unaffected

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posterior proximal soft tissue compartment of the lower leg used for stump formation. A more proximal level of amputation is indicated if there is a doubt of soft tissue viability, which excludes BKA and preservation of the knee joint. In these situations, either a through-knee amputation (TKA) or an above-knee amputation (AKA) may be considered.

In our hospital, one major limb amputation is done per week. The Gritti–Stokes form of TKA is the first choice for patients not eligible for a BKA. This technique mainly consists of a through-knee amputation (considered as an AKA by some authors because of the supracondylar amputation level at the distal femur) with the creation of a pedicled patella flap consisting of the patella, patellar ligament, and overlying soft tissue. After osteotomy of the distal femur at the level of the adductor tubercle and resection of the articular surface of the patella, the anterior flap is rotated in order to cover the femur defect while performing a patellofemoral arthrodesis.

The GSA was first popularized in the 1960s–1970s and showed an advantage, especially in primary wound healing, compared to traditional TKA. Patient satisfaction and walking abilities were, however, worse. The suggested causes were a mobile patella, stump pain, and difficulties in adapting the prosthesis (2, 3). In recent years, the surgical technique and prosthesis fitting was improved. The newer and modified Gritti–Stokes amputation proposes better stabilization of the patella by angulating the femur transection at 10–15° and using a solid femoral–patellar suture to achieve a femoral–patellar arthrodesis. However, surgical techniques vary widely, and no standardized technique exists.

The aim of this paper is to describe our surgical technique and experience with GSA in patients undergoing major lower-limb amputation and to highlight the important steps of this procedure.

Gritti–Stokes amputation, trans-knee amputation, and above-knee amputation

AKA is the most widely used procedure if a BKA cannot be considered. However, the stump nonhealing rate has been reported as high as 10% (1), and the rehabilitation is usually very slow and cumbersome, especially in elderly and frail patients. This situation is partially due to a non-weight-bearing stump and the need for an ischial weight-bearing prosthesis.

The TKA technique has been associated with frequent skin breakdown since the bulbous ends of the femur are only covered by a thin layer of cutaneous and subcutaneous tissue, inevitably rubbing continuously against the prosthesis. In addition, with this technique, the patella remains unstable when sutured against the posterior knee joint capsule, which may cause pain and recurrent patella dislocation (1). For these reasons, the re-amputation rate has been reported to be as high as 10–13% (4, 5).

More recently, the Gritti–Stokes form of trans-genicular amputation (GSA) has regained attention in situations where BKA is contraindicated to circumvent the disadvantages of TKA or AKA.

GSA allows for better preservation of lower limb function, with respect to femur length, stable end-bearing stump, and good primary wound healing. The preservation of the proximal part of the femoral condyles and the pre-patellar skin allows for distal propping, and when maintaining the maximal length of the femur, the lever arm is maximal (6). Small studies show promising results with lower blood loss and fewer postoperative complications (7, 8). GSA is therefore of particular interest in older frail adults and is, in our opinion, an underestimated alternative for patients currently undergoing AKA.

Recent literature focusing on patients undergoing GSA for trauma injury showed a significantly longer femoral stump and increased rate of walking wearing the prosthesis without any assistance as compared to AKA (9). This substantially higher ambulatory rate achieved with GSA is believed to be related to a longer and better-shaped end-bearing conical stump and the preservation of proprioceptive components of the patella flaps.

Recently, a postoperative mortality rate of 32% at 1 year, 52% at 3 years, and 63% at 5 years for AKA at an average age of 70, in patients suffering predominantly from PVD was reported ($n = 126$; average age 70.1 years) (10). These results are similar to those found in the literature for older and morbid patients, ranging from 7% to 22% within 1 month (11) to 60–70% at 5 years (12). However, they compete with those reported for trauma patients, who are generally younger, low-risk patients in good health, with fewer accompanying comorbidities and a high potential for rehabilitation.

However, recent literature related to GSA, TKA, and AKA is relatively scarce. Panhelleux *et al*. are pointing out the difficulty in summarizing the literature comparing traditional TKA, GSA, and AKA, and the impossibility of providing a valuable answer on the superiority of one surgical technique. Even focusing on the GSA, the surgical technique vary widely in different series, especially regarding femoral–patellar arthrodesis and its outcome (13).

Patient selection and preoperative assessment

GSA was used in patients suffering from traumatic injury or PVD of the lower extremity considered too extensive to be treated by BKA or in patients without

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Figure 1

Skin incision, medial.

sufficient rehabilitation potential to be equipped with a prosthesis. The preoperative condition of the patient is important. For a patient who walks and has full autonomy, the knee has to be maintained if possible, and BKA is favored. However, for patients with compromised walking abilities, the knee can be sacrificed to enhance the chances of wound healing (14). In patients where BKA is not possible, we do favor GSA above TKA or AKA because we do believe in better wound healing chances and a higher ambulatory rate, respectively.

A certain number of details must be considered to achieve satisfactory results, especially in this older population.

First, special attention should be paid to the particular profile of the elderly adult with PVD. The mean age of patients with PVD requiring surgical revascularization is 70–90 years. Most of them have a long history of smoking and associated diseases such as chronic obstructive pulmonary disease, coronary heart disease, malnutrition, vitamin deficiency, hypertension, and diabetes with associated renal insufficiency. In this particular population, a careful evaluation of the ambulatory rehabilitation potential and optimal preoperative treatment of comorbidities by collaborating with a general practitioner is essential before performing major lower-limb amputations.

Secondly, in addition to a careful analysis of the patient's general health status and rehabilitation potential, a compulsory evaluation of local tissues and vascularization is essential for determining an optimal amputation level. Blood supply and healthy tissue are critical to the success of the procedure. Besides a careful clinical evaluation of the level of ischemia based on the localization of the lesions and ischemic signs of skin ischemia, a variety of objective methods are advocated to determine the appropriate level of limb amputation, such as segmental Doppler blood pressure measurement, photoplethysmography, skin perfusion pressure, and transcutaneous oximetry with TcPO2 measurement. Unfortunately, none of these measures alone reliably predicts wound healing. We

Figure 2

Skin incision, anterior.

rely on careful clinical skin evaluation, the presence or absence of peripheral pulses, capillary recoloration time, and angiology examination with plethysmography, segmental Doppler blood pressure, and TcPO2 measurements. We accept threshold TcPO2 values at

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Figure 3

Skin incision, lateral.

the planned amputation level of >40 mm Hg for diabetic patients and >35 mm Hg for nondiabetic patients.

The most frequent complications after GSA remain stump infection and wound dehiscence. Up to 30–45% of lower limbs are colonized with potentially pathogenic germs at the time of amputation (15, 16), and therefore, antibiotics are administered before and after the operation. However, there is no evidence of the utility of prophylactic antibiotic administration in those situations in the literature. Sadat *et al*. showed a lower complication rate after 5 days of postoperative antibiotics, and Dunkel *et al.* showed no impact of antibiotic prophylaxis on stump infection.

Nevertheless, we do administrate prophylactic antibiotics for all GSA procedures. In case of infection, the microbiologist is routinely involved in the appropriate administration of antibiotics.

Surgical technique

Positioning

After general or loco-regional anesthesia with the patient in dorsal decubitus, skin disinfection and draping are performed at the proximal femur level to recognize leg rotation and the pelvic position for

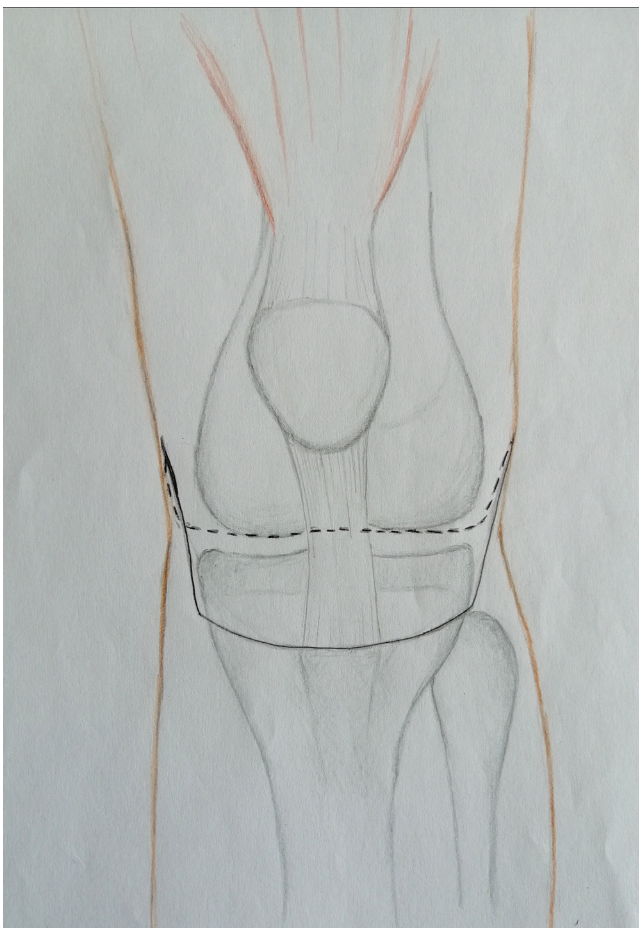

Figure 4

Skin incision, front.

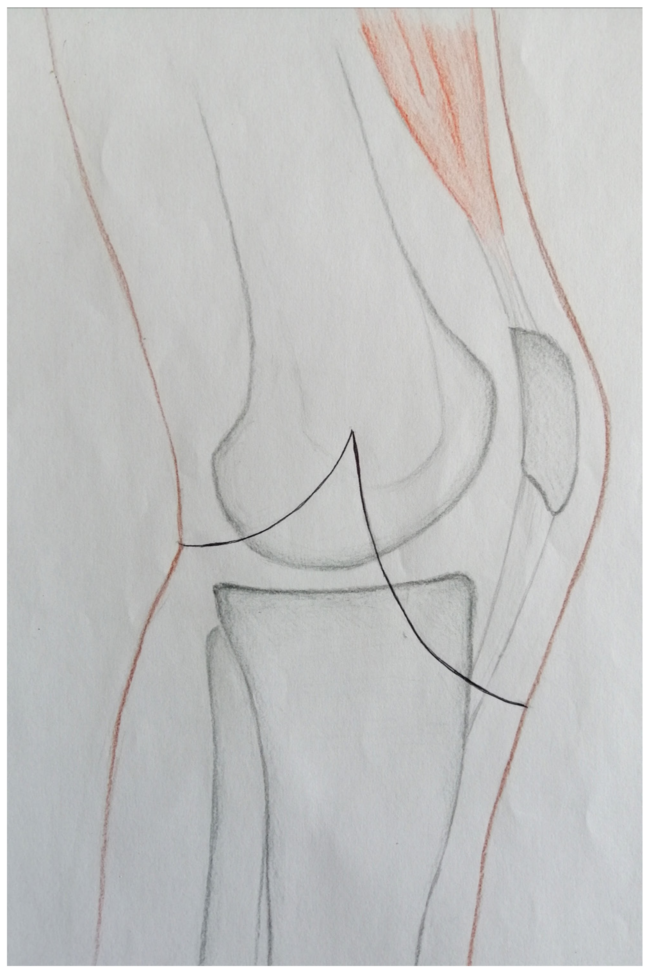

Figure 5

Skin incision, profile.

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Figure 6

Soft tissue incision and exposure of the knee joint.

optimal anatomical orientation. No tourniquet is used, not even placed, to avoid additional ischemia at the level of amputation.

Flap design

The surgery starts with meticulously drawing the flap to ensure optimal covering and vascularization. Anatomical landmarks, including the patella, the lateral and medial femoral condyle, and the tibial tubercle, are identified. The anterior aspect of the flap is outlined transversally at the level of the tibial tubercle. The outline is then continued in a caudad-to-cephalad direction to the midline of the knee up to the distal part of the femur. This is followed by outlining the transverse posterior aspect of the flap, which is at the level of the planned femoral cut (Figs. 1, 2, 3, 4, and 5).

A longer anterior and a shorter posterior soft tissue flap are created, which positions the incision line on the posterior thigh, out of the charging zone, once it is sutured (9, 17). Additionally, the curves between the anterior and posterior flaps should be smooth to minimize the risk of creating 'dog ears' (17).

Skin and soft tissue incision

A full-thickness incision is performed, including skin, subcutaneous tissue, and fascia, without using coagulation. The saphenous vein and nerve are individually ligated and divided. The patellar tendon, pes anserinus tendons, and tibial band insertions are elevated subperiosteally, and the knee joint is entered

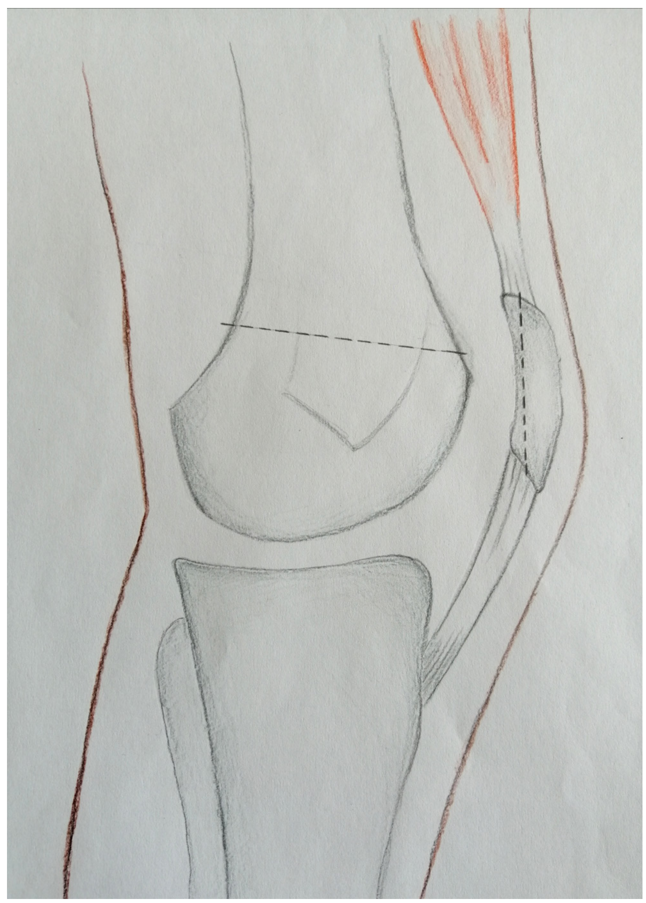

Figure 7

Femoral and patellar bone cut for the modified Gritti–Stokes amputation.

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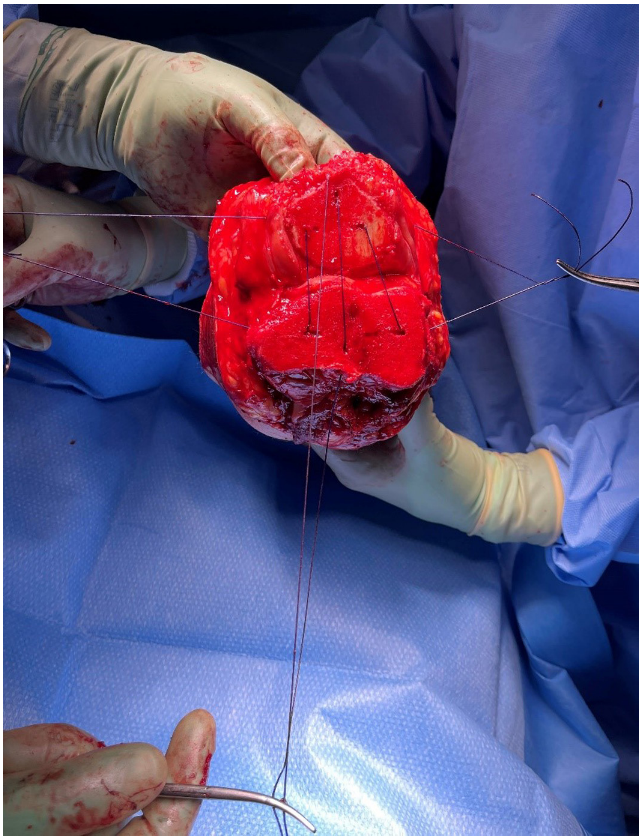

Figure 8

Suture of a femoropatellar arthrodesis in a modified Gritti–Stokes amputation.

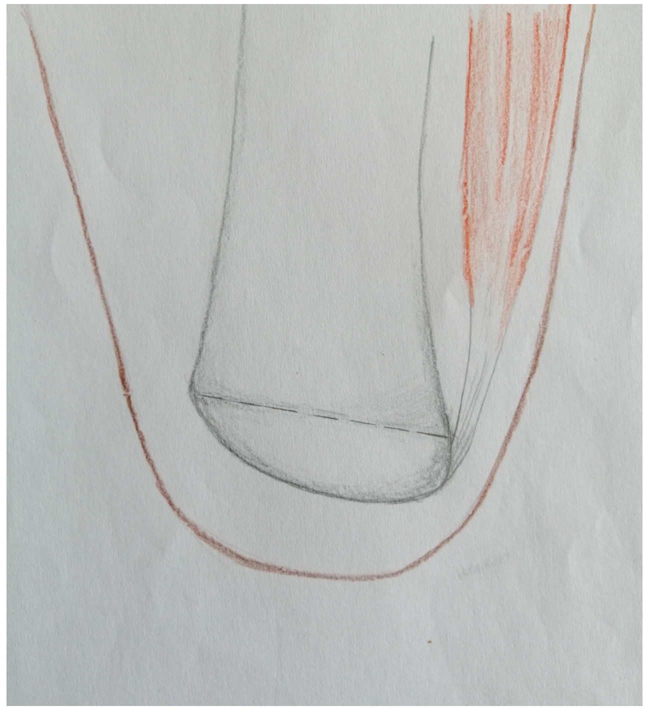

Figure 9

Gritti–Stokes amputation: femoropatellar arthrodesis.

while dividing the cruciate and collateral ligaments. A subperiosteal dissection of the femur is performed, combined with total synovectomy, to prevent postoperative effusion (Fig. 6).

Femoral and patellar cuts

The distal femur is exposed subperiosteally up to the adductor tubercle and cut with a high-speed saw just beneath the adductor tubercle while preserving the vast adductor insertion. An angled femoral cut of 10–15° is performed from anterior-distal to posterior-proximal to prevent patellar dislocation. Afterward, a flat patellar cut is performed with a wide saw blade, parallel to the anterior surface of the patella, followed by copious irrigation of the femur and patella cut to remove osseous and cartilaginous debris (Fig. 7).

Posterior dissection

The cut femoral condyle bone is retracted distally while maintaining the gastrocnemius tendon origins. The popliteal neurovascular structures are then

Figure 10

Modified Gritti–Stokes amputation after skin closure.

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Figure 11

Postoperative X-ray image femur AP after modified Gritti–Stokes amputation.

individually dissected, ligated, and divided. The popliteal artery and vein are ligated with an additional proximal piercing ligature of the popliteal artery using nonabsorbable suture material. The gastrocnemius tendons are divided distally, as is the biceps femoris tendon at the level of its distal myotendinous junction. After completion of the amputation, copious irrigation and hemostasis are performed.

Patellofemoral arthrodesis

The patella with the prepatellar skin is advanced to cover the femoral stump and acts as a shield that resists friction and mechanical stress (18).

The main complication after GSA in our practice was painful nonunion of the patella to the femoral shaft. This finding agrees with other reports and can be overcome by an angled femoral osteotomy and femoropatellar sutures to stabilize the patella and improve the healing of the arthrodesis. We perform a 10–15° angulation of the femur condyle transection (1, 9) This angle varies in the literature

Figure 12

Postoperative X-ray image femur profile after modified Gritti–Stokes amputation.

from 10–15° to 45° (9, 17, 19). The angle creates a bone surface on which the patella is easily applied (19), reducing the dislocation forces on the patella and therefore decreases the risk of nonunion.

In addition, a solid suture technique with a tight and stable approximation of the patella to the distal femur shaft is essential. We usually drill three holes of 2.5 mm into the patella and the femur, and the patella is tightly sutured to the distal femur using large absorbable (Vicryl 2) sutures while pressing the patella against the femur. If the bone quality seems insufficient to ensure stability, we increase the number of stitches up to 4–6 to overcome patellofemoral instability and nonunion. In addition, every effort is made to completely remove the cartilage, which is a condition sine qua non for a successful arthrodesis (9, 17). To enhance stability, we suture the patellar tendon on the fascia of the posterior thigh musculature.

Different fixation techniques are described to ensure femoropatellar arthrodesis. Theriot *et al.* closed the fascia around the patella and fixed the patellar tendon on the posterior tendons. The authors reported rewarding results compared with AKA but did not mention their pseudoarthrosis rate (17). Lim *et al.* fixed the patella by suturing the surrounding soft tissues without trans-bone fixation (19). In contrast, Taylor *et al.* used six trans-bone holes and nonabsorbable sutures for femoropatellar fixation. With correctly fastened sutures, adequate compression of the arthrodesis can be achieved. In addition, the pes anserinus tendons, biceps femoris tendon, and posterior thigh musculature are sutured to the patellar tendon (9). Martin *et al.* also used trans-osseous stitches but only on the distal patella/posterior femur (6). Patellar nonunion is a frequently observed postoperative complication after GSA, which may be accompanied by persistent patellar pain. However, with the modified GSA technique by performing the angulation of the femoral cut, this complication is less common (1, 3). Middleton described one case of symptomatic mobile patella

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in 18 amputations. Interestingly, he observed several patella displacements on postoperative X-rays, which were asymptomatic and with firm stumps on clinical examination (20). In case of persistent patellar pain after GSA, we suggest performing an X-ray imaging to exclude femoropatellar pseudoarthrosis (Figs. 8 and 9).

Soft tissue closure

The soft tissues are closed in layers by using interrupted sutures. The pes anserinus tendons are sutured to the biceps femoris tendon, followed by suturing of the remaining part of the gastrocnemius musculature to the patellar tendon. The subcutaneous tissue is adapted, and the skin is closed with interrupted, simple stitches as follows: start stitching in the middle of the wound, then stitch halfway between the first stitch and the end of the wound, and then continue with stitches halfway between two stitches. Avoid additional trauma and ischemia by gentle handling without using forceps. The stump is cleaned, and a soft sterile dressing is applied while avoiding any additional stump compression (Fig. 10).

Postoperative care

Bed rest is prescribed for 5 days to prevent edema and hematoma formation. Afterward, progressive mobilization is started (3 × 5–10 min verticalization/day), and stitches are usually removed after 21 days. A compressive stump dressing and a weight-bearing prosthesis are then applied with the implication of an experienced prosthetist. During the learning curve, we propose verifying the achieved patella-femoral bone position with X-ray (anterior and lateral views) imaging (Figs. 11 and 12).

Regarding postoperative rehabilitation potential, after AKA, only 20% of the patients can walk with a prosthesis compared to 60% of patients with BKA (21). Theoretically, GSA has advantages compared to AKA, and some small series have shown promising results. GSA seems to simplify the rehabilitation and prosthesis fitting, with similar outcomes as BKA (22). However, as mentioned above, the literature discussing GSA is limited, and the evidence is weak.

In conclusion, our experience with GSA is an excellent surgical option for patients requiring major lower limb amputations when BKA cannot be considered. However, particular attention must be paid to careful preoperative evaluation and optimization of comorbidities. Moreover, a meticulous surgical technique is warranted, including atraumatic tissue handling, as well as an optimal patellofemoral arthrodesis technique.

Further studies are necessary to compare the different surgery techniques and their outcomes to give valuable results.

ICMJE Conflict of Interest Statement
The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the study reported.

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Patient consent
The authors confirm consent has been obtained from each patient for use of their images within this article.

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