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Original article

Prosthetic fitting associated with better survival at 5 years after above-knee amputation due to vascular insufficiency

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ABSTRACT

Background: Individuals requiring non-traumatic Gritti-Stokes amputation or mid-thigh amputation usually have multiple comorbidities that place them at high risk of mortality.
Objective: To determine survival rate 5 years after Gritti-Stokes and mid-thigh amputation in individuals with vascular insufficiency and to identify the predictors of survival.
Methods: We conducted a retrospective observational study including all individuals with vascular insufficiency who underwent amputation from September 2007 to December 2015 in our University Hospital. The indication for amputation was limb necrosis in 86% of cases, infection in 10%, and complications with the stump (discomfort, neuroma or scar dehiscence) in 4%. Medical records were analysed to determine factors and comorbidities. The date of death was retrieved from the national death registry at a minimum of 5 years after amputation. Cox proportional-hazard regression was used to estimate associations between factors and post-amputation survival with hazard ratios (HR) and 95% confidence intervals (CIs).
Results: We included 126 people with vascular insufficiency (83 men), mean age was 70 years [20; 97]; eighty-nine participants (71%) died during the study period. Survival rate was 68% at 1 year, 48% at 3 years and 37% at 5 years. Survival was associated with prosthetic fitting (HR 0.306 [95% CI 0.180; 0.521], $p<0.001$) and length of stay (HR 0.992 [95% CI 0.987; 0.997], $p = 0.003$). Conversely, limb necrosis was associated with a lower survival rate (HR 3.801 [95% CI 1.615; 8.949], $p = 0.002$). In a secondary multivariable analysis, Gritti-Stokes amputation was the only factor positively associated with prosthetic fitting (odds ratio 7.407 [95% CI 2.439; 22.489], $p<0.001$).
Conclusions: The survival rate at 5 years after Gritti-Stokes and mid-thigh amputation in people with vascular insufficiency was 37%. Prosthetic fitting was independently associated with better survival, and Gritti-Stokes amputation was the only factor positively related to prosthetic fitting.

Introduction

Lower limb amputation is associated with a high rate of directly attributable postoperative mortality, ranging from 7% to 22% within 30 postoperative days. This high rate is related to procedures performed in older people with numerous comorbidities [1]. Survival after lower limb amputation ranges from 50% to 80% at 1 year and 30 to 40% at 5 years [2].

People who survive also have to cope with significant morbidity and reduced autonomy and independence, whether they are fitted with a prosthesis or not [3]. The number of amputations continues to increase with the aging population [4, 5], the increase in the prevalence of diabetes (11% among people over 65 years; the incidence of amputations in this population ranges from 78 to 704 per 100,000 people per year [6, 7]), and the increase in cardiovascular risk factors and subsequent peripheral vascular disease [8].

These observations raise questions about the best overall care for these individuals. Despite advances in vascular surgical techniques and wound care, lower limb amputation remains the last resort when all so-called "conservative" options have been implemented

Abbreviations: HR, Hazard Ratio; ASA, American Society of Anesthesiologists

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and have not been able to resolve limb ischemia. Amputation can stop pain and scarring in well-vascularized regions.

The level of amputation is chosen according to vascularization but is also related to mortality after amputation [2]. Moreover, a recent study found that prosthetic-limb wearing was related to better survival [9]. In the context of an above-knee amputation, many surgeons directly choose mid-thigh amputation. Gritti-Stokes amputation, which essentially differs from a through-knee amputation by the metaphyseal cut of the femur and the "osteosynthesis" of the patella on it [10], has biomechanical advantages for future prosthetic fitting (e.g., less energy consumption and cardiac stress [11]) compared to a mid-thigh amputation. However, as compared with through-knee amputation, Gritti-Stokes amputation is mostly associated with an increased risk of scarring complications and therefore revision surgery because of poor local vascularization, more distal amputation and greater surgical difficulty [12]. A poorer cosmetic result with a different center of rotation in the sitting position with the knees flexed and a smaller choice of prosthetic equipment are other disadvantages.

Studies have analysed the survival rate after different levels of amputation, but few have compared Gritti-Stokes and mid-thigh amputations.

The main objective of this study was to determine the survival rate after Gritti-Stokes and mid-thigh amputations with a follow-up of at least 5 years. The secondary objective was to identify the factors related to mortality. We hypothesised that Gritti-Stokes amputation and prosthetic fitting would be related to a better survival rate than mid-thigh amputation and no prosthetic fitting.

Methods

Study design

This was an observational, retrospective study conducted in a single University Hospital. We included all individuals who had undergone a Gritti-Stokes or mid-thigh type of amputation between 1st September 2007 and 31st December 2015 (with a minimum 5-year follow-up). It is important to note that in our hospital we performed no through-knee amputations but only true Gritti-Stokes amputations with osteosynthesis of the patella on the cut femur; all participants were amputated for ischemic reasons, and the level of cut was decided according to Transcutaneous Pressure of Oxygen values.

Ethical approval was obtained (ID 2017-02331).

Data collection and participants

The dates of death were retrieved from the national death register. Participants had to be at least 18 years old at the time of recruitment, and only amputations for vascular sequelae were included. The files of eligible participants were first identified and retrieved, then analysed (Fig. 1). The main outcome was death.

Surgical indication was determined from the medical files. We also retrieved comorbidities from discharge letters and other medical documents in participants' files. We analysed active smoking with Pack Year Unit number and the presence of chronic obstructive pulmonary disease, cardiovascular risk factors such as high blood pressure, hypercholesterolemia, type I or II diabetes both insulin-dependent and insulin-independent, history of heart disease and stroke and chronic renal failure with or without dialysis. We also collected the American Society of Anesthesiologists (ASA) anesthesia score [13]. To determine the potential link between mortality and factors extrinsic to the individual, we analysed the level of education (profession practised when the person entered the hospital), place of residence (home versus medical/social institution) and type of health insurance (public versus private). Finally, we collected information about fitting with a prosthetic limb or not.

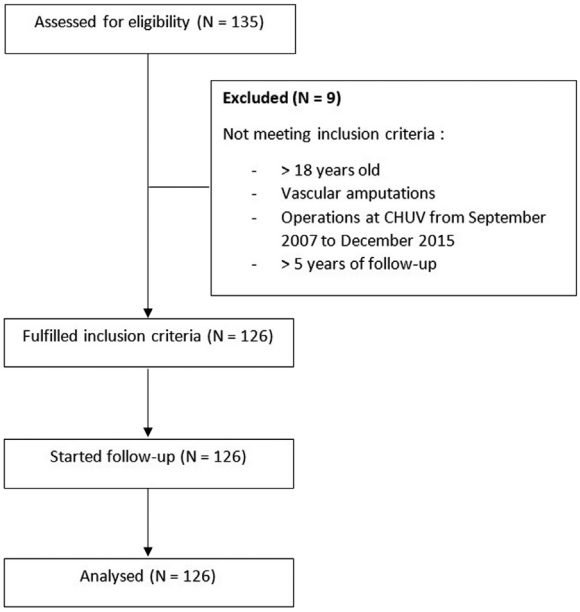

Fig. 1. Study flow-chart.

Statistical analysis

We estimated the association between each identified factor and the duration of post-amputation survival with Cox proportional-hazard regression analysis. Participants who were still alive at the end of the follow-up were censored. We first screened each predictor individually, only adjusting for age at amputation. A variable selection procedure was used, selecting all predictors with $p<0.20$ on univariate analysis by using the "gvselect" command in Stata. We retained the model that minimized the Bayesian information criterion.

A secondary analysis was performed to assess the association between predictors and post-amputation prosthetic fittings. We used logistic regression to first screen each factor individually and then kept the best subset of predictors among those with $p<0.20$ on univariate analysis to find a model that minimized the Bayesian information criterion.

All statistical analyses were performed with Stata 16.0 (StataCorp, College Station, TX, USA). $P<0.05$ was considered statistically significant.

The reporting of the study follows the STROBE guidelines.

Results

Participants

From September 2007 to December 2015, we included 126 eligible participants (83 men); the mean age was 70 years (range 20 - 97) at the time of the surgery.

Descriptive data

Table 1 shows participant characteristics. Most participants had cardiovascular risk factors (smoking, high blood pressure, hypercholesterolemia and diabetes). For 86 participants, the ASA score was 3; for 17, 2; for 21, 4; and for 2, 5. Finally, 91 participants had already retired at the time of their intervention.

Surgical indication

The indication for surgery was lower limb peripheral artery disease PAD with necrosis for 86% of participants, infection for 10% and complications with the stump (discomfort, neuroma or scar

Table 1
Characteristics of participants with amputation due to vascular insufficiency (n = 126).

Age, mean (SD), median (min-max)	70 (15), 71 (20–97)
Sex, female	43 (34)
Heart disease	53 (42)
Stroke	23 (18)
Smoker	52 (41)
Chronic obstructive pulmonary disease	45 (36)
High blood pressure	91 (72)
Hypercholesterolemia	61 (48)
Diabetes type I	3 (2)
Diabetes type II	49 (39)
Chronic renal failure	42 (33)
Dialysis	27 (21)
Cirrhosis	3 (2)
America Society of Anesthesiologists score	
2	17 (14)
3	86 (68)
4	21 (17)
5	2 (1)
Residence, institution	10 (8)
Employment status	
Retired	91 (72)
Disability insurance	14 (11)
Working	21 (17)
Insurance, private	9 (7)
Amputation indication	
Necrosis	108 (86)
Infection	13 (10)
Complications	5 (4)
Gritti-Stokes amputation	77 (61)
Duration of surgery (minutes), mean (SD), median (min-max)	81 (31), 77 (25–210)
Length of hospital stay (days), mean (SD), median (min-max)	61 (49), 47 (3–210)
Complications	48 (38)
Reoperation	31 (25)
Revision	24 (19)
Revascularization	80 (64)
Prosthesis	54 (43)
Survival	
1 year	85 (68)
3 years	60 (48)
5 years	47 (37)

Data are n (%) unless otherwise indicated.

dehiscence) for 4%. Overall, 77 amputations involved the Gritti-Stokes technique and 49 were mid-thigh amputations. Postoperatively, 43% of participants were fitted with a prosthesis and underwent rehabilitation.

Main results, postoperative survival

During the study period, 79 participants died. The survival rate was 68% at 1 year postoperative, 48% at 3 years and 37 at 5 years (Fig. 2).

Other analyses, influencing factors

We assessed the association of each factor with survival, adjusting for age. In a multiple Cox regression model, prosthetic fitting, necrosis and extended hospitalization were the most associated with survival. Results are shown in Table 2. Survival was better with Gritti-Stokes amputation and extended hospitalization. People fitted with a prosthesis after a Gritti-Stokes amputation typically had extended hospital stays. However, amputation for necrosis had a negative influence on survival.

Since prosthetic fitting was strongly associated with longer survival, we then identified factors related to prosthetic fitting (Table 3). In the multiple logistic regression model, factors that were most strongly associated with the potential for prosthetic fitting were

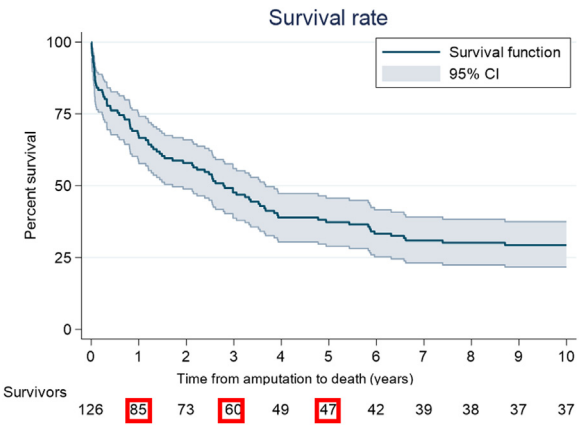

Fig. 2. Survival rate by year.

Gritti-Stokes amputation, young age, no hospital complications, low ASA score and no heart disease (Table 3). A limitation of our study is that we have no information about the type of prosthetic mechanism used.

Missing data

Among the 79 participants who died, 7 were lost to follow-up, and the date of death was unknown for 2.

Discussion

In this retrospective study, we investigated long-term survival as well as comorbidities and other risk factors that may be associated with survival in individuals with Gritti-Stokes or mid-thigh amputation for a vascular indication. Our study confirmed the poor prognosis of these major amputations: survival rate was 68% at 1 year, only 48% at 3 years and 37% at 5 years.

These survival rates are comparable to those found in the literature. A meta-analysis [2] of studies similar to ours found a 38% survival rate 5 years after major amputation. That study also highlighted that the presence of diabetes and chronic kidney disease had a negative impact on long-term survival. In our study, these were the indications for amputation for necrosis, which is the only independent factor that decreased long-term survival. Necrosis is likely the final stage of the progression of ischemia, itself the consequence of all known cardiovascular risks. Another meta-analysis [8], focusing more on individuals with amputation and concomitant diabetes, also found similar mortality rates, with a survival rate of 20% to 38% at 5 years. Finally, a study [14] that included only individuals over 70 years old found that survival was 25% at 5 years. These mortality rates are high and are related to the significance of the surgery performed. Nonetheless, we must not ignore that beyond the operative risk and direct postoperative complications, in most cases (85% in our study), amputation is for arterial insufficiency of the lower limbs. This disease is already a significant risk factor for premature mortality. In another study [15], the survival rate for critical limb ischemia was 56% at 1 year and 15% after 5 years. Therefore, these data must be weighed when discussing major lower limb amputation.

We found a favourable effect of post-amputation prosthetic fitting on survival. As we hypothesized, prosthetic fitting was independently associated with higher survival rates, regardless of the type of amputation procedure. To our knowledge, only the study by Singh et al. [9] also showed a link between post-amputation prosthetic fitting and survival. Our study seems to confirm those results. However, we analysed individuals with similar amputation levels (trans-tibial and trans-femoral in Singh et al.) and with a longer follow-up (5 years; only 3 years in Singh et al.). Therefore, we are the first to show that prosthetic fitting is an independent factor associated with better

Table 2
Factors associated with survival (Cox simple and multiple regression models).

	Cox regression models			Multiple Cox regression models		
	HR*	95% CI	*p*-value	HR	95% CI	p-value
Length of hospital stay	0.995	0.990;1.001	**0.084**	0.992	0.987; 0.997	**0.003**
Duration of surgery	0.998	0.991; 1.005	0.631			
Female sex	0.841	0.538; 1.313	0.445			
ASA score 2	0.620	0.259;1.487	0.284			
ASA score 4–5	1.023	0.595; 1.759	0.934			
Gritti-Stokes amputation	0.701	0.454; 1.084	**0.110**			
Left side amputation	0.799	0.525; 1.215	0.294			
Necrosis	2.609	1.131; 6.019	**0.025**	3.801	1.615; 8.949	**0.002**
Hospital complications	0.889	0.569; 1.389	0.606			
Reamputation	1.184	0.741; 1.892	0.480			
Reoperation	0.794	0.435; 1.452	0.454			
Revascularisation	1.117	0.713; 1.748	0.629			
Heart disease	1.227	0.809; 1.861	0.336			
Stroke	0.781	0.441; 1.385	0.398			
Smoking	0.955	0.602; 1.514	0.844			
COPD	1.095	0.683; 1.754	0.706			
High blood pressure	0.606	0.380; 0.968	**0.036**			
Hypercholesterolemia	1.100	0.722; 1.674	0.658			
Type II diabetes	1.429	0.938; 2.178	**0.097**			
Chronic renal failure	1.513	0.979; 2.338	**0.062**			
Dialysis	1.398	0.838; 2.330	0.199			
Institution vs home residence	1.763	0.849; 3.662	0.128			
Retired	0.987	0.516; 1.886	0.968			
Private insurance	0.710	0.325; 1.548	0.389			
Prosthesis	0.375	0.228; 0.616	**<0.001**	0.306	0.180; 0.521	**<0.001**

* adjusted for age.
ASA, American Society of Anesthesiologists; COPD, chronic obstructive pulmonary disease, HR, hazard ratio; 95% CI, 95% confidence interval.
Bold font indicates statistically significant results (p-value < 0.20).

survival with this kind of amputation. We suggest that this is because prosthetic fitting permits individuals to stand and walk, reducing complications relating to lying, sitting and sedentarism. Hence, individuals probably have better control of their comorbidities.

Because of a convincing association between prosthetic fitting and survival, we conducted a secondary analysis of factors related to prosthetic fitting. Gritti-Stokes amputation was independently related to the ability to fit prostheses for these older participants

Table 3
Factors associated with prosthetic fitting: univariate and multivariate logistic regression analyses.

	Univariate analysis			Multivariate analysis		
	OR	95% CI	p-value	OR	95% CI	p-value
Length of hospital stay	1.006	0.998; 1.013	**0.126**			
Duration of surgery	1.001	0.989; 1.012	0.913			
Sex, female	0.702	0.330; 1.492	0.357			
ASA score 2	5.390	1.647; 17.643	**0.005**			
ASA score 4–5	0.223	0.071; 0.702	**0.010**	0.168	0.043; 0.667	**0.011**
Gritti-Stokes amputation	3.700	1.678; 8.158	**0.001**	7.407	2.439; 22.489	**<0.001**
Side of amputation	1.047	0.516; 2.126	0.899			
Necrosis	0.421	0.151; 1.171	**0.097**			
Hospital complications	0.455	0.214; 0.967	**0.041**			
Reamputation	1.346	0.596; 3.039	0.474			
Reoperation	2.692	1.075; 6.741	**0.034**			
Revascularisation	1.273	0.608; 2.662	0.522			
Heart disease	0.398	0.189; 0.839	**0.015**	0.304	0.114; 0.806	**0.017**
Stroke	0.404	0.148; 1.108	**0.078**			
Smoking	2.471	1.192; 5.123	**0.015**			
COPD	2.241	1.066; 4.712	**0.033**			
High blood pressure	1.176	0.532; 2.600	0.688			
Hypercholesterolemia	0.982	0.485; 1.989	0.959			
Type II diabetes mellitus	0.430	0.202; 0.914	**0.028**			
Chronic renal failure	0.745	0.350; 1.587	0.446			
Dialysis	0.895	0.377; 2.125	0.802			
Residence, home vs institution	0.308	0.063; 1.512	**0.147**			
Retired	0.187	0.080; 0.440	**<0.001**			
Private insurance	1.072	0.274; 4.197	0.920			
Age	0.928	0.896; 0.960	**<0.001**	0.909	0.872; 0.947	**<0.001**
Complication	0.455	0.214; 0.967	**0.041**	0.286	0.107; 0.765	**0.013**

ASA, American Society of Anesthesiologists; COPD, chronic obstructive pulmonary disease, OR, odds ratio; 95% CI, 95% confidence interval.
Bold font indicates statistically significant results (p value < 0.20).

with multimorbidity. In our study, 77 participants underwent Gritti-Stokes amputation and 49 mid-thigh amputation. Survival rates were lower after mid-thigh than Gritti-Stokes amputation and individuals were less often fitted with a prosthesis. Before choosing the type of amputation, one must know the purpose of the amputation: an amputation in a healthy area to avoid more serious complications regardless of the point of amputation or amputation with high functional rehabilitation objectives. As already mentioned, the Gritti-Stokes amputation has biomechanical advantages for easier future prosthetic fitting (e.g., less energy consumption and cardiac stress [16]). However, the surgical technique is more complex, with a slower learning curve, which increases the risk of wound healing complications and therefore revision surgeries. The Gritti-Stokes amputation is offered to individuals with a more favourable vascular area. Conversely, the higher mortality in the event of mid-thigh amputation is probably related to it being offered to the weakest persons: those with a more critical vascular disease area and who do not have the aim of a future prosthesis. Hence, the point of amputation and thus the prosthetic fitting and long-term survival are strongly related, with the underlying comorbidities affecting all outcomes.

Finally, one must analyze this observation as a whole. The final decision of whether to fit a prosthesis depends on many factors. Age and comorbidities are better represented by ASA scores. To this, the point of amputation is also added, which depends on the localized condition (vascularization and skin condition). All these factors tip the balance either for or against a prosthesis. Participants fitted with a prosthesis were younger and had lower ASA scores and fewer cardiovascular comorbidities. Therefore, they were in “better health” and would have a better chance of succeeding in their rehabilitation and benefiting from the prosthetic fitting.

As we expected, comorbidities affected long-term survival to some extent. Participants with diabetes and/or chronic renal failure had lower post-operative survival rates than other participants. Chronic diseases causing numerous systemic complications are obviously deleterious for postoperative prognosis. However, these factors are probably better described with the ASA score. These more “global” characteristics suggested that participants had a poorer general condition and therefore were more likely to have complications. These results echo those found in the 2 meta-analyses cited above [8, 14]. Conversely, people who were still professionally active had a better survival rate, probably because of their better general health condition. However, as we already said, the only factor independently associated with survival was limb necrosis, probably because it is the synthesis of all the pathologies and the final indication for amputation. Finally, factors that independently affected future prosthetic fitting and consequently survival were Gritti-Stokes amputation, young age, no hospital complications, low ASA score and no heart disease. This result is a strength of our study.

The mean age of the participants was high, around 70 years. Therefore, participants were already inherently fragile and more likely to have postoperative complications and higher long-term mortality [11]. A comparison of differences in mortality rates between vascular procedures or amputation in individuals over 70 years of age with peripheral artery disease found higher mortality with major amputation than with revascularisation or even conservative treatment [2]. All this tends to confirm the seriousness of the surgical procedure and its risks, which must be balanced with other treatment possibilities to offer the best long-term result for the participant.

What clearly emerges from all these analyses is the presence of serious comorbidities in the participants. From high blood pressure to chronic renal failure, including diabetes and cardiovascular history, these individuals are at risk of complications from the outset, with or without surgery. Therefore, in addition to treating peripheral artery disease and its complications either with surgery or conservatively, one must manage the participant’s overall condition, dealing with the various associated diseases and controlling them as best as possible. A recent Danish study [17] also highlighted this by showing a significant reduction in long-term mortality in the context of multidisciplinary care. Mortality at 30 days decreased from 35% to 16% and 1-year mortality decreased from 59% to 37%. These data confirm the importance of providing care in a specialized medical center with all disciplines involved with these individuals. The Lausanne University Hospital has a network for people with amputation that facilitates comprehensive care with multidisciplinary monitoring, including during the prosthetic fitting process, to provide the best possible support for the participant. This situation has the negative effect of extending hospital stays for several weeks, which is only possible in a customized health system.

Limitations

The retrospective aspect of our study is its main limitation. It is difficult to determine the severity of the diseases in individuals from the medical files, which may explain the lack of influence or the minimizing of this influence on long-term survival. Nevertheless, the preoperative ASA score is the best representation of the health status of the individual. However, to our knowledge, no prospective study has examined differences in long-term mortality by type of amputation or treatment (surgical or conservative). A

A larger cohort might demonstrate a real direct influence of the Gritti-Stokes amputation on survival. This observational cohort study could only reveal associations between factors, without determining cause and effect. Finally, the cause of death was not always known, so we could not conclude clearly and affirmatively as to whether it was related to the amputation procedure or not.

Conclusions

Gritti-Stokes amputation and mid-thigh amputations for vascular deficiency remain associated with high mortality despite progress in medical care, surgery and rehabilitation. Nevertheless, our study is the first to demonstrate that prosthetic fitting in Gritti-Stokes amputation or mid-thigh amputation is an independent predictor of better survival in these frail, polymorbid individuals and should be considered whenever possible. Our study also confirms that prosthetic fitting remains a complex procedure affected by many biological factors. Gritti-Stokes amputation was the only factor positively related to prosthetic fitting and its success. We believe the most important message that emerged from this study is that medical teams confronted with these therapeutic choices should consider Gritti-Stokes amputation as a valuable alternative to mid-thigh amputation in people with vascular insufficiency whenever possible to enhance the chances of prosthesis fitting and by consequence survival. Studies with larger sample sizes should be conducted to further examine and confirm these results.

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Declarations of competing interest

None.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.rehab.2022.101727.

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