From the Peripheral Vascular Surgery Society

Comparative results of open lower extremity revascularization in nonagenarians

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Introduction: **The average lifespan in the United States continues to lengthen. We have observed a similar trend in our patients, with an increased number of nonagenarians presenting for evaluation of vascular disease. This study evaluated outcomes of lower extremity revascularization in patients aged ≥90 years.**

Methods: **The vascular registry at Albany Medical College was retrospectively reviewed for all lower extremity bypasses performed between 1996 and 2006. We evaluated patient demographics, indications, procedure, patency rates, and complications. Patients were divided into groups based on age ≥90 years (≥90 group) and <90 years (<90 group). Variables were evaluated by χ^2 analysis. Outcomes were prepared using life-table methods and compared with log-rank analysis.**

Results: **During the last 10 years, 5443 lower extremity bypasses were performed on patients aged <90 years and 150 on patients aged ≥90 years. The <90 group had significantly more men (61.4% vs 29.3%) and was obviously younger, at 68 years (range 7-89 years) vs 92 years (range, 90-101 years). The <90 group had more comorbidities in terms of diabetes, active tobacco use, and hypercholesterolemia. No significant difference was noted in coronary artery disease or chronic renal insufficiency between the groups. Critical limb ischemia as an indication was significantly higher in the ≥90 group (149 [99%] vs 4472 [82%]; $P < .0.5$). Strikingly, the primary patency was significantly higher in the ≥90 group at 4 years (77% vs 62%; $P < .05$). Complication and amputation rates did not differ between the groups. Perioperative (15% vs 3%; $P < .05$) and 1-year (45% vs 11%; $P < .05$) mortality rates were significantly higher in the ≥90 group.**

Conclusion: **Lower extremity bypass for nonagenarians offers acceptable patency and limb salvage but at a significantly higher mortality rate. (J Vasc Surg 2009;49:1459-64.)**

The American population has continued to age during the last two census periods, and the population aged ≥85 years is projected to increase by 43% from 2000 to 2010.[1] The number of nonagenarians referred for limb ischemia to our offices has increased accordingly with the aging population. Limb revascularization and limb salvage in the elderly has been studied and deemed safe; however, no series has addressed the nonagenarian population exclusively.[2-4] We analyzed our experience with vascular reconstruction in patients aged ≥90 years of age by reviewing our results for limb salvage and patient survival.

METHODS

The vascular registry at Albany Medical College was retrospectively reviewed for all lower extremity bypasses performed between 1996 and 2006. We evaluated patient demographics, indications, procedure, patency rates, complications, and mortality rates. Comorbidities for each patient were defined as a medical diagnosis actively being treated by a primary physician. The indications for procedure were recorded based on standard nomenclature.[5]

The management strategy involved all patients with potentially salvageable limbs undergoing standard contrast angiography before any revascularization. If the treating physician determined the lesion was not amenable to angioplasty or stenting, then the options of open bypass, primary amputation, and observation were discussed with the patient. A final decision was agreed upon according to patient and individual surgeon preference. The treatment decision was founded on overall medical condition and general patient appearance.

The methods and specifics of revascularization was decided by group conference, and the best possible option was used to salvage the limb regardless of age. Most procedures were performed under general anesthesia using low-dose heparin anticoagulation, without the need for protamine after the procedure.

Postprocedural follow-up involved pulse volume recordings ≤2 weeks, at 3 months, and then every 6 months. Interrogation of all autogenous bypass grafts with duplex ultrasound imaging occurred every 6 months according to practice protocol. Limb salvage was defined as avoidance of below or above knee amputation. Patency rates were recorded in terms of primary vs secondary patency. The patients were divided into groups based on age ≥90 years and <90 years. The variables were compared using χ^2 analysis. The outcomes were prepared using life-table methods and compared with log-rank analysis.

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Table I. Demographics

Variable[a]	*<90 y*	*≥90 y*	P
No. of patients	5443	150	
Male	3341 (61.4)	44 (29.3)	<.05
Age, y	68 (7-89)	92 (90-101)	<.05
Diabetes	2697 (50)	38 (25)	<.05
Tobacco use	1747 (32.1)	10 (6.7)	<.05
Coronary disease	3439 (63.2)	91 (60.8)	NS
Hypertension	4087 (75.1)	108 (72)	NS
Hypercholesterolemia	2754 (50.6)	45 (30)	<.05
COPD	646 (11.9)	63 (42)	<.05
Renal insufficiency	1066 (19.6)	21 (14)	NS

COPD, Chronic obstructive pulmonary disease; *NS,* not significant.
[a]Categoric data are expressed as number (%); continuous data as mean-(range).

Table II. Indications

Indication	*<90 y* *No. (%)*	*≥90 y* *No. (%)*	P
Claudication	971 (17.8)	1 (0.7)	<.05
Rest pain	1194 (21.9)	31 (20.7)	NS
Ulcer	1995 (36.7)	76 (50.7)	<.05
Gangrene	1057 (19.4)	39 (26)	<.05
Aneurysm	144 (2.7)	3 (2)	NS
Trauma	44 (0.8)	0	NS
Atheroemboli	38 (0.7)	0	NS

NS, Not significant.

RESULTS

Between 1996 and 2006, 5593 lower extremity bypasses were performed at our institution, 5443 in the <90 group and 150 in the ≥90 group. The <90 group had significantly more men than the ≥90 group (3341 [61.4%] vs 44 [29.3%]; *P* < .05). The <90 group had more risk factors for atherosclerosis such as diabetes (2697 [50%] vs 38 [25%]; *P* < .05), tobacco use (1747 [32.1%] vs 10 [6.7%]; *P* < .05), and hypercholesterolemia (2754 [50.6%] vs 45 [30%]; *P* < .05). The groups were similar in the presence of coronary artery disease, hypertension, and renal insufficiency. The ≥90 group had more chronic obstructive pulmonary disease than the <90 group (63 [42%] vs 646 [11.9%]; *P* < .05; Table I).

The indications for peripheral revascularization were different between the two groups secondary to the ≥90 group having significantly more critical limb ischemia (Table II). Ten procedures in the ≥90 group were performed for symptoms resulting from a failed older bypass. These 10 revascularizations all used the common femoral artery for inflow and the outflow was a tibial vessel. The inflow for the bypasses was similar between groups except for increased use of the superficial femoral artery in the ≥90 group, (39 [26%] vs 980 [18%]; *P* < .05; Table III). The outflow vessels were different with regards to more above knee (1133 [20.8%] vs 19 [12.7%]; *P* < .05) and below knee (1228 [22.6%] vs 22 [14.7%]; *P* < .05) popliteal artery bypasses in the <90 group and more use of the peroneal artery in the ≥90 group (55 [36.7%] vs 919 [16.9%]; *P* < .05; Table IV). The conduit used for bypass was similar in both groups (Table V). The groups sustained similar postoperative complications, except for a higher wound infection rate (399 [7.3%] vs 1 [0.7%]; *P* < .05) in the <90 group (Tables VI and VII).

The overall primary patency rates were better at 4 years in the ≥90 group, at 77.3% vs 62.1% (*P* < .05), but this significance was lost after 4 years of follow-up due to the small number of survivors (Fig 1). Secondary patency rates at 5 years were not significantly different, at 82.9% vs 70.8% (*P* = NS; Fig 2). Further comparison based on popliteal vs tibial outflow showed no significant difference in patency between the <90 and ≥90 groups (Fig 3). All revisions of the ≥90 group bypass stenoses were performed using open

Table III. Inflow vessels

Inflow	*<90 y* *No. (%)*	*≥90 y* *No. (%)*	P
Graft/iliac artery	458 (8.4)	12 (8)	NS
Common femoral artery	2686 (49.4)	80 (53.3)	NS
Superficial femoral artery	980 (18)	39 (26)	<.05
Profunda femoris artery	472 (8.7)	8 (5.3)	NS
Axillary artery	5 (0.1)	0	NS
Above knee popliteal artery	154 (2.8)	2 (1.3)	NS
Below knee popliteal artery	598 (11)	9 (6)	NS
Tibioperoneal trunk	3 (0.1)	0	NS
Anterior tibialis artery	39 (0.7)	0	NS
Posterior tibialis artery	22 (0.4)	0	NS
Peroneal artery	21 (0.4)	0	NS
Dorsalis pedis artery	5 (0.1)	0	NS

NS, Not significant.

Table IV. Outflow vessels

Outflow	*<90 y* *No. (%)*	*≥90 y* *No. (%)*	P
Above knee popliteal artery	1133 (20.8)	19 (12.7)	<.05
Below knee popliteal artery	1228 (22.6)	22 (14.7)	<.05
Tibioperoneal trunk	39 (0.7)	0	NS
Anterior tibialis artery	825 (15.2)	19 (12.7)	NS
Posterior tibialis artery	742 (13.6)	19 (12.7)	NS
Peroneal artery	919 (16.9)	55 (36.7)	<.05
Dorsalis pedis artery	523 (9.6)	16 (10.7)	NS
Plantar artery	27 (0.5)	0	NS
Tarsal artery	7 (0.1)	0	NS

NS, Not significant.

Table V. Conduit

Conduit	*<90 y* *No. (%)*	*>90 y* *No. (%)*	P
Prosthetic	1355 (24.9)	33 (22)	NS
In situ bypass	2239 (41.1)	73 (48.7)	NS
Excised vein	1283 (23.6)	30 (20)	NS
Spliced vein	566 (10.4)	14 (9.3)	NS

NS, Not significant.

Table VI. Local complications

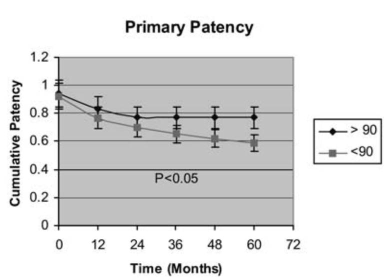
Complications	*<90 y No. (%)*	*≥90 y No. (%)*	P
Wound infection	399 (7.3)	1 (0.7)	<.05
Lymphocele	41 (0.8)	1 (0.7)	NS
Bleeding	188 (3.5)	2 (1.3)	NS
Immediate occlusion	307 (5.6)	7 (4.7)	NS
Arteriovenous fistula	76 (1.4)	4 (2.7)	NS
Retained valve	56 (1)	0	NS
Proximal vein bypass stenosis	123 (2.3)	1 (0.7)	NS
Middle vein bypass stenosis	150 (2.8)	2 (1.3)	NS
Distal vein bypass stenosis	135 (2.5)	2 (1.3)	NS
Native artery inflow stenosis	61 (1.1)	1 (0.7)	NS
Native artery outflow stenosis	54 (1)	1 (0.7)	NS
Graft infection	76 (1.4)	1 (0.7)	NS

NS, Not significant.

Table VII. Systemic nonfatal complications

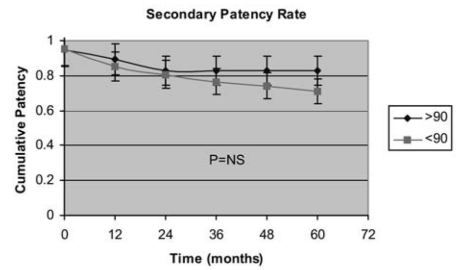
Nonfatal complications	*<90 y No. (%)*	*≥90 y No. (%)*	P
Cardiac	57 (1.1)	2 (1.3)	NS
Renal	8 (0.2)	1 (0.7)	NS
Pulmonary	18 (0.3)	0	NS
Stroke	7 (0.1)	0	NS
Sepsis	6 (0.1)	0	NS
Colon ischemia	1 (0.02)	0	NS
MOS	17 (0.3)	0	NS

MOS, Multisystem organ failure; *NS,* not significant.



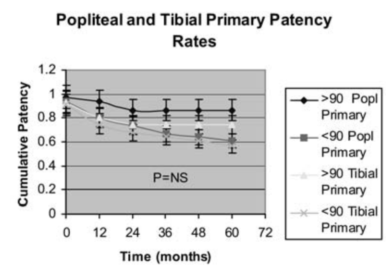
Limbs at Risk		12 months	24 months	36 months	48 months	60 months
<90	5443	4226	2328	1630	1135	815
>90	150	118	65	39	29	13

Fig 1. Primary patency. Data are presented with the standard deviation.



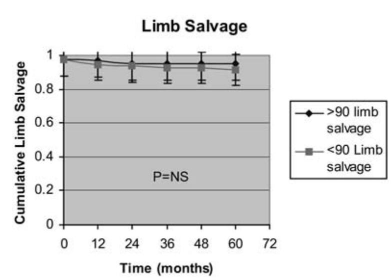
Limbs at Risk		12 months	24 months	36 months	48 months	60 months
<90	5443	4372	2567	1835	1286	938
>90	150	119	69	42	31	15

Fig 2. Secondary patency. Data are presented with the standard deviation.



Limbs at Risk		12 months	24 months	36 months	48 months	60 months
<90 popliteal	2361	1904	1152	835	578	430
>90 popliteal	41	31	18	8	6	3
<90 tibial	3082	2326	1191	820	584	402
>90 tibial	109	87	47	31	23	10

Fig 3. Popliteal and tibial patency patentcy rates. Data are presented with the standard deviation.



Limbs at Risk		12 months	24 months	36 months	48 months	60 months
<90	5443	4372	2573	1839	1291	942
>90	150	119	69	42	31	15

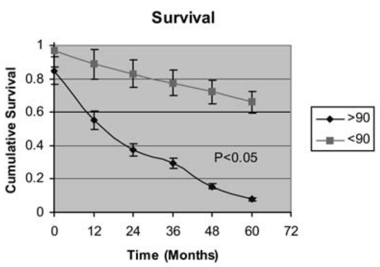
Fig 4. Limb salvage rates. Data are presented with the standard deviation.

techniques, and 13 bypass stenoses were treated percutaneously in the <90 group. The limb salvage rates between in the groups were also similar (Fig 4).

The ≥90 group mortality rate was significantly higher than the <90 group at 30 days (15.1% vs 3.3%; $P < .05$), 1 year (44.9% vs 11.3%; $P < .05$), and 5 years (92.2% vs 34.0%; $P < .05$; Fig 5). The causes of death in the 30-day postoperative period in the ≥90 group were cardiac in 19 (86.4%), stroke in two (9.0%), and multisystem organ failure in one (4.5%). The mean length of follow-up was 28 months (range, 1-140 months) for the <90 group and 22 months (range, 1-74 months) for the ≥90 group.

DISCUSSION

The United States population is continually aging, and with this trend, more nonagenarian patients have been referred to our facility for treatment of limb ischemia. The



Patients at Risk		12 months	24 months	36 months	48 months	60 months
<90	5443	4372	2573	1839	1291	942
>90	150	119	69	42	31	15

Fig 5. Survival rates. Data are presented with the standard deviation.

a 90-year-old American has an average life expectancy of approximately 5 years, and this finding may preclude simple observation of a limb with severe pain or gangrene.[6] The goal of our practice is to salvage limbs, relieve ischemic pain, and preserve ambulatory status whenever feasible. If the patient is deemed an acceptable risk from a medical and surgical standpoint, revascularization is offered. The aging of the population is a newly evolving process, and little data are available to support or negate open revascularization in nonagenarians. Multiple series have focused on peripheral revascularization for octogenarians and nonagenarians, but this is a large series primarily focused on limb revascularization in the nonagenarian population. The ≥90 group had a better primary patency rate and a similar limb salvage rate compared with the <90 group, but these results are tempered by a significantly higher mortality rate in the ≥90 group.

The <90 and ≥90 groups were obviously different in terms of age, but were also different in sex. The ≥90 group had a preponderance of women, which may be a reflection of the overall longer life expectancy of women in the United States. The rate of diabetes, tobacco use, and hypercholesterolemia in the ≥90 group was significantly less than the <90 group, and this may have led to less atherosclerotic related death. The groups did not differ in rates of hypertension, coronary artery disease, or renal insufficiency. This finding is difficult to explain, except that emergence of these risk factors may have evolved later in life in the nonagenarians, which in turn may not have had time to affect survival. The rate of diabetes in the ≥90 group was approximately half that of the <90 group. This finding may be explained by the higher early mortality in diabetic individuals or by the general observed paucity of obese patients in the ≥90 group.

The indications for revascularization were different between the two groups. Almost all procedures performed on the ≥90 group were for limb-threatening ischemia. The preponderance of critical limb ischemia in the ≥90 group is secondary to a general resistance to operate for any reason except for limb preservation in this population. It is difficult to elucidate the pattern of disease and symptoms because of the lack of data on claudicant patients treated nonoperatively in the more elderly population. The atheroemboli indication for bypass was for treatment of an ulcerated plaque that resulted in blue toe syndrome. Two symptomatic popliteal aneurysms were treated in the ≥90 group for compression-related symptoms.

The types of inflow used were largely similar between groups; however, the superficial femoral artery (SFA) was used significantly more in the ≥90 group. An explanation for this observation may be less plaque formation at the origin of the SFA in this group. Whether this finding demonstrates a different age-related distribution of atherosclerosis or pattern of calcification in nonagenarians is difficult to determine without the availability of the angiograms. An alternative explanation is that the SFA is technically easier to expose and less dissection of the vein is needed for an in situ reconstruction, possibly allowing a quicker procedure for the patient. The inflow and overall procedures were generally kept simple to maximize benefit and minimize complications in the ≥90 group. This is in contrast to the more aggressive procedures that were used in the <90 group, such as a dorsalis pedis to tarsal artery autogenous bypass.

The difference in atherosclerotic risk factors may have led to better primary patency in the ≥90 group. A more likely explanation is patient selection: The ≥90 patients without optimal bypass options may not have been offered an operation based on surgeon discretion.

The vascular registry is very procedure-oriented and, unfortunately, does not include ankle brachial indices, TransAtlantic Inter-Society Consensus classifications, or even outflow vessel characteristics. These data points might have demonstrated a divergence in disease patterns between the age groups that could have helped explain some of the patency findings. The registry also does not elaborate on the extent of ulceration or gangrene. These data might have offered more insight into different disease patterns between groups.

The difference in secondary patency and limb salvage was insignificant between the groups. A small gap was noted between late patency and limb salvage in the ≥90 group, and this was a reflection of patency and not of patient mortality.

Most cohorts in most series addressing the elderly population consist of octogenarians, with only a few nonagenarians included. Our patency and limb salvage rates are comparable with those series, but our ≥90 group had a much higher mortality rate. The ≥90 group mortality rate was 15.1% at 30 days and 44.9% at 1 year. Most of the early deaths were secondary to perioperative cardiac events. The prior studies, consisting mostly of octogenarians, had 1-year mortality rates of 8% to 22%.[3,4,7-10] Those studies were able to advocate an aggressive approach to revascularization based on acceptable mortality rates. Perioperative mortality rates were 2.5% for septuagenarians and 3.2% for octogenarians. The significantly increased mortality rate in the ≥90 group may temper the enthusiasm for aggressive revascularization. The increased mortality rate of the ≥90 group may also have created a distinction between octogenarians and nonagenarians when patients are classified as "elderly."

Our series has a few limitations. The first pertains to selection bias. There may have been patients deemed too infirm to tolerate an operation who were treated nonoperatively. Data were not collected on nonoperatively treated patients or their mortality or limb salvage status.

Another limitation was the lack of data on preoperative ambulatory and independent living status, which are two factors that are strong predictors of survival after peripheral revascularization.[2,7] Our database also did not keep records of postoperative ambulation and quality of life status; we do not know if any of the surviving ≥90 patients returned to independent living.

There has been a nationwide trend toward percutaneous intervention for peripheral vascular disease, but our series did not compare percutaneous intervention with open procedures in the ≥90 group. Our peripheral stenting database was initiated in 1999 and up to 2007, and in that time 1085 peripheral stents were placed. Septuagenarians accounted for 314 (28.9%) and octogenarians accounted for 187 (17.2%) peripheral stent procedures. Nonagenarians accounted for nine lower extremity peripheral stents, with one periprocedural cardiac-related death. Percutaneous intervention may offer a less invasive alternative to an open procedure; however, 1-year mortality rates remain significantly elevated in the elderly population in these series.[11,12] In accordance with the population changes, our group has experienced an increase in the number of open revascularization procedures in the nonagenarian population. In light of these new mortality findings, our management strategy is evolving toward using more aggressive percutaneous methods or even nonoperative treatment.

CONCLUSIONS

Our series demonstrates that peripheral revascularization can be performed with good patency and limb salvage rates in nonagenarians, but with a significantly increased mortality rate. These findings may temper the enthusiasm for an aggressive approach to limb salvage in the elderly population and also may have created a distinction between octogenarians and nonagenarians when classifying patients as elderly.

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AUTHOR CONTRIBUTIONS

Conception and design: JH, SR, RD, PP, JT, MM
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Data collection: JH, SR, RD, PP, JT, MM
Writing the article: JH, SR
Critical revision of the article: JH, SR, RD, PP, JT, MM
Final approval of the article: JH, SR, RD, PP, JT, MM
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Overall responsibility: JH

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DISCUSSION

Dr Brian Nolan (Lebanon, NH). I think your question is an interesting one. The most pertinent finding, in my opinion, was that nearly half of the patients over age 90 don't survive 1 year following major lower extremity revascularization. This begs the question whether there is value in doing it and how do you select those patients to whom it is of value? So, the question I have is, have you analyzed your data using multivariate regression to determine independent risk factors that might help you with patient selection? As a follow-up to that, have you looked at any other age cohorts, like age greater than 80?

Finally, I think in your paper you point out that you reviewed your entire revascularization experience, including claudicants, of which there were significantly more claudicants in the age <90 group. If you controlled for claudication, are your findings still significant?

Dr Jeffrey Hnath. We did not specifically use a multivariate analysis study, but you bring up an interesting point, and we will see if there are enough patients in the '90 age group to perform a further analysis. We did not specifically look at the 80-year-old or even the 70-year-old patient data; we felt that the octogenarian population had previously been studied.

There were about 20% more claudicants in the <90 population in our study, and only one patient ≥90 received a bypass for claudication. If we segregate by indication we may find a slight change in the mortality rate.

Dr Ruth Bush (Temple, Tex). In your Kaplan-Meier curve, you showed a high mortality rate, which you would expect for folks over 90, but you didn't include the number at risk or the confidence interval bars on your patency rate. I think just my comment would be that that would be important to include in the manuscript, because I suspect those numbers trickle off quite a bit.

Dr Erica Mitchell (Portland, Ore). Did you look at the 30-day and 1-year mortality rates of 90-year-olds who underwent amputation, and if so, were they different to that after bypass?

Dr Hnath. We did review our amputation patients, and actually, the 30-day mortality rate in our above knee amputations is anywhere from 30% to 45%.

Dr Lee Goldstein (New York, NY). In the last decade you reported almost 5500 bypasses, which works out to almost 1.5 bypasses every day. I would imagine that volume in the nonagenarian population in the last few years has significantly decreased with the advent of aggressive endovascular interventions.

I think the patients that have gotten to be in their 90s would have a different form of vascular disease if they have gotten that far. With your patency rates being especially better in that population, have you thought about comparing, or at least breaking down, your time frame into an earlier vs a later period and looking at the impact of endovascular therapies on these older patients?

Dr Hnath. We looked at our endovascular numbers and we had a surprisingly low number of nonagenarians. We performed a percutaneous intervention on nine patients in that time span, with only one mortality. If we get more numbers, then maybe we can look into it a little further.

Dr Jim Watson (Seattle, Wash). This study provides some data for what's been my practice for a long time, which is to minimize interventions in the older population while avoiding amputation. As you point out, amputations are devastating in older patients. However, I have occasionally tolerated small ulcers or mild gangrene in an elderly patient without intervening, as long as it doesn't progress. Some of these problems have healed, and some patients have died of other causes without treatment of their ischemia. Obviously, some lesions need intervention. But any intervention on the elderly carries significant risk of complications, and whatever we can do to avoid amputation and keep them out of the hospital is what we should focus on.

Dr Hnath. I agree. We need to be selective about how we treat this population.