

Limb Salvage Success Utilizing Microsurgical Free Tissue Transfer In Patients Despite Moderate To Severe Medial Arterial Calcification

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Introduction

- Medial arterial calcification (MAC) is a non-atherosclerotic vascular process involving calcium deposition in the arterial tunica media.
- Unlike atherosclerosis, MAC stiffens arteries without occluding flow, leading to impaired vessel compliance.
- MAC is strongly associated with advanced age, diabetes, CKD, and ESRD.
- It is radiographically distinct and highly visible on plain X-rays, with a characteristic “rail-tracking” pattern.
- MAC is emerging as a risk marker for major limb events and mortality in patients with critical limb-threatening ischemia.
- Despite this, its effect on outcomes in microsurgical limb salvage remains unknown.
- This study investigates the prognostic significance of MAC in patients undergoing LE free tissue transfer (FTT).

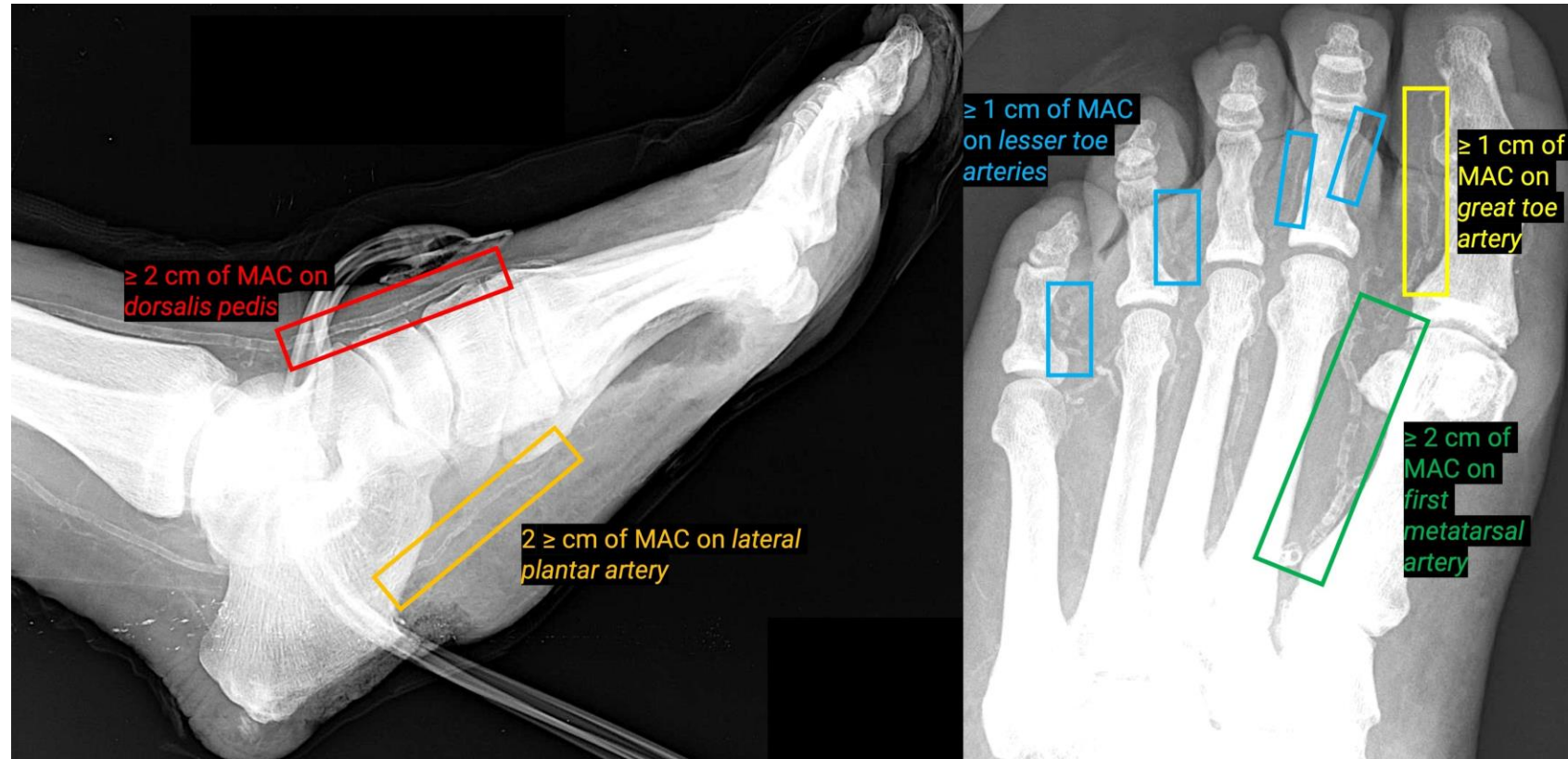
Objective

To assess the impact of moderate and severe MAC on microsurgical, limb salvage, and survival outcomes following LE free tissue transfer.

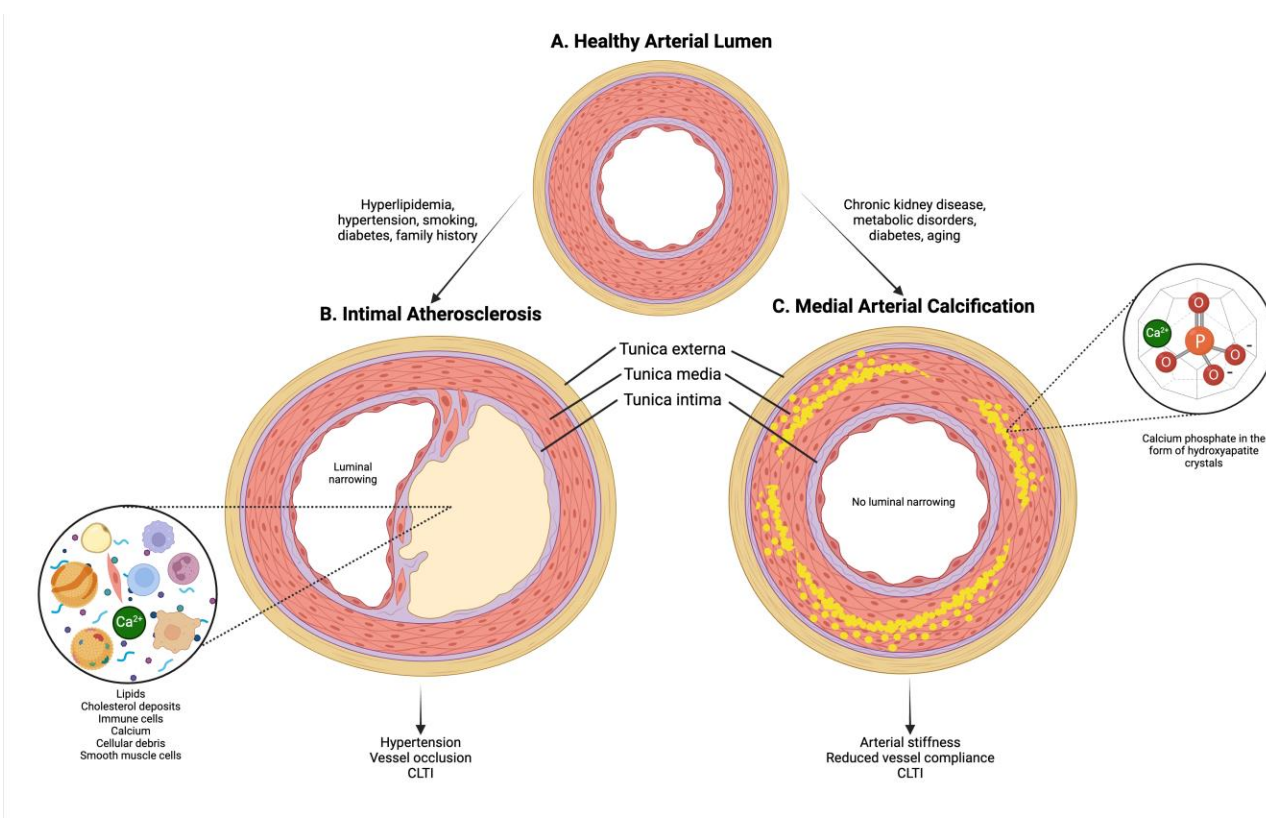
Methods

- Retrospective review of 320 LE FTTs (2011–2024) at a tertiary limb salvage center.
- Patients stratified using the Ferraresi et al. MAC classification based on pre-op pedal X-rays (**Figure 1**)
 - No MAC (0–1 calcified sites)
 - Moderate MAC (2–3 sites)
 - Severe MAC (4–5 sites)
- Primary outcomes:
 - Major amputation
 - Surgical reintervention
 - Post-op vascular intervention
 - Major adverse limb events (MALEs = amputation or reintervention)
 - Mortality

Results



Above. Pedal MAC Scoring System.



Above. Differences between intimal calcification (atherosclerosis) and MAC.

During the study period 320 cases were performed:
12 (3.8%) had moderate MAC and 32 (10.0%) had severe MAC

	Clinical Outcomes.				P-Value
	All Limbs No. (%)	Absent MAC No. (%)	Moderate MAC No. (%)	Severe MAC No. (%)	
	320 (100.0)	276 (86.3)	12 (3.8)	32 (10.0)	
Flap Complications					
Any Flap Complication	93 (29.1)	71 (25.7)	4 (33.3)	18 (56.3)	0.033*
Takeback (POD0-7)	14 (4.5)	11 (4.1)	1 (8.3)	2 (6.3)	0.410
Flap Salvage	10 (71.4)	7 (63.6)	1 (100.0)	2 (100.0)	1.000
Partial Flap Necrosis	12 (3.8)	7 (2.5)	1 (8.3)	4 (12.5)	0.020*
Dehiscence	54 (16.9)	44 (15.9)	1 (8.3)	9 (28.1)	0.172
Infection	42 (13.1)	25 (9.1)	5 (41.7)	12 (37.5)	<0.001
Flap Success (POD0-12)	310 (96.9)	269 (97.5)	10 (83.3)	31 (96.9)	0.055
Long-Term Follow-Up Outcomes					
Final Follow Up Duration, months (median [IQR])	22.2 [32.5]	21.7 [32.5]	21.4 [41.8]	24.4 [32.7]	0.849
Ambulatory at Final Follow Up	272 (85.3)	239 (86.9)	10 (83.3)	23 (71.9)	0.065
Major Adverse Limb Event	152 (47.5)	116 (42.0)	9 (75.0)	28 (84.4)	<0.001
Unscheduled Return to OR for Podiatric Intervention	148 (46.3)	114 (41.3)	8 (66.7)	26 (81.3)	<0.001
Postoperative Angioplasty	30 (9.4)	19 (6.9)	1 (8.3)	10 (31.3)	*
Time to Angioplasty, days (median [IQR])	127 [171]	156 [213]	210 [-]	47.5 [153]	0.189
Major LE Amputation	46 (14.4)	33 (12.0)	3 (25.0)	10 (31.3)	0.009*
Time to MLEA, days (median [IQR])	225.5 [303]	263.0 [277.0]	13.0 [158.0]	101.0 [216.0]	0.012*
Mortality					
1-Year Mortality	8 (2.5)	6 (2.2)	0 (0.0)	2 (6.3)	0.411
5-Year Mortality	22 (6.9)	15 (5.4)	1 (8.3)	6 (18.8)	0.023*

*Bold-face values indicate statistical significance, $p < 0.05$. Abbreviations: MAC, medial arterial calcification; POD, postoperative day; IQR, interquartile range.

Patient Characteristics

- Patients with MAC were significantly more comorbid:
- Charlson Comorbidity Index: highest in severe MAC ($p < 0.001$)
 - Diabetes: 96.9% (severe MAC) vs. 81.2% (absent MAC), $p < 0.001$
 - PAD: 100% in severe MAC ($p < 0.001$)
 - CKD: 50.0% (severe MAC) vs. 20.3% (absent MAC), $p = 0.005$
 - ESRD: 31.3% (severe MAC) vs. 11.6% (absent MAC), $p < 0.001$
 - CHF & solid organ transplant also more common ($p < 0.01$)

Wound severity was higher in MAC patients:

- Larger wound area ($p = 0.018$)
- Higher osteomyelitis prevalence ($p < 0.05$)

Pre-op vascular disease was more advanced in MAC groups:

- ↑ Tibial occlusion and ↓ runoff ($p < 0.05$)
- Pre-op revascularization: 54.6% (moderate), 31.3% (severe), $p = 0.001$

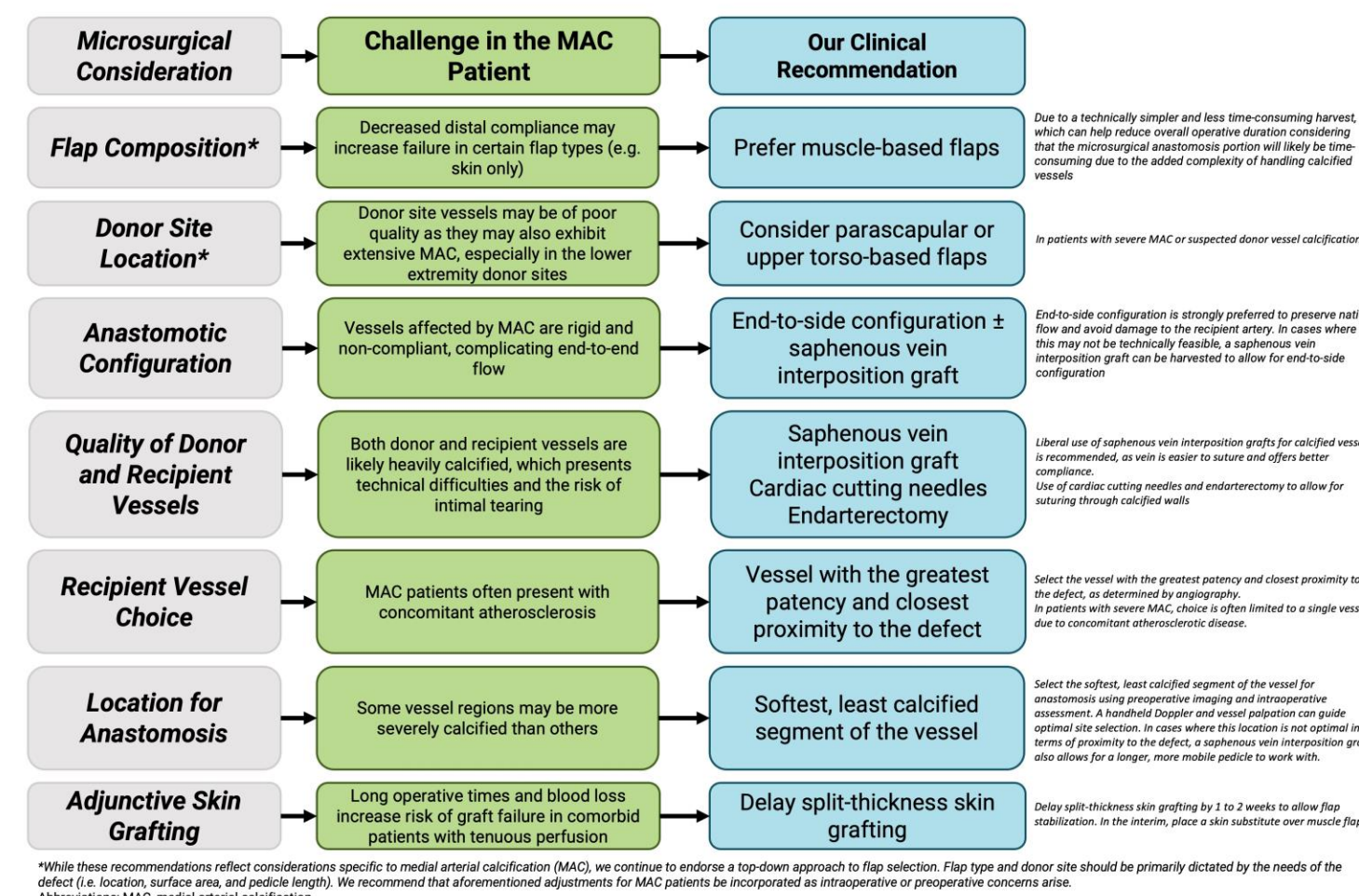
Univariate Analysis

Patients with moderate and severe MAC demonstrated a significantly higher rates of flap complications (absent: 25.7% vs. moderate: 33.3% vs. severe: 56.3%; $p = 0.033$), major adverse limb events (42.0% vs. 75.0% vs. 84.4%; $p < 0.001$), surgical reintervention (absent: 41.3% vs. 66.7% vs. 81.3%; $p < 0.001$), postoperative vascular intervention (6.9% vs. 8.3% vs. 31.3%; $p < 0.001$), major amputation (12.0% vs. 25.0% vs. 31.3%; $p = 0.009$), and 5-year mortality (5.4% vs. 8.3% vs. 18.8%; $p < 0.001$).

Multivariate Analysis

Severe MAC independently increased the odds of major adverse limb events by 3.7-fold (CI: 1.3–11.1, $p = 0.018$) and unscheduled surgical reintervention by 3.1-fold (CI: 1.1–8.6, $p = 0.031$). MAC did not remain significantly predictive of major amputation, postoperative vascular intervention, 5-year mortality, or flap complications.

Clinical and Technical Considerations in MAC Patients Undergoing LE FTT



Discussion

- Severe MAC is associated with profoundly worse limb-related outcomes, despite preserved flap survival.
- Over 80% of patients with severe MAC required reoperation or experienced major adverse events.
- MAC appears to be a marker of systemic disease—not a direct surgical contraindication, but a red flag for high morbidity.
- Technical challenges include vessel rigidity, need for grafting, and extended operative time.
- Despite risks, limb salvage is still achievable in this population with a rigorous vasculoplastic approach.
- Pedal X-ray MAC scoring is a simple, effective tool for preoperative risk stratification and patient counseling.

Conclusion

Limb salvage using LE FTT is possible in patients with severe MAC but comes with significant morbidity. MAC should prompt preoperative optimization, multidisciplinary planning, and cautious patient selection—not automatic exclusion.

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