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Torsion Does Not Affect Early Vein Graft Patency in the Rat Femoral Artery Model

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Abstract

Background

- Torsion of microvascular vein grafts (1 mm diameter) is a commonly cited reason for graft failure in the clinical setting.
- Interpositional vein graft torsion is a common technical error made by the surgeons in microsurgery training courses.
- The objective of this study was to determine if torsion would lead to early vein graft failure in non-survival surgery rat models.

Methods

- 25 Sprague-Dawley rats were divided into 5 equal cohorts.
- Cohorts were labeled based on degree of vein graft torsion (0, 45, 90, 135, and 180 degrees) (Fig. 1).
- Torsion was created in the vein grafts at the distal arterial end by mismatching sutures placed between the proximal end of the vein graft and the distal arterial end.
- Average vessel diameter was 1 mm
- Vein graft patency was then verified via two methods, 2 and 24 hours post-operation.

Results

- All vein grafts were patent 2 and 24 hours post-operation.
- Average blood flow rate measurements for 0, 45, 90, 135, and 180 degrees of torsion 2 hours post-operation: 0.37 ± 0.02, 0.38 ± 0.04, 0.34 ± 0.01, 0.33 ± 0.01, and 0.29 ± 0.02 ml/min respectively.
- Average blood flow rate measurements for 0, 45, 90, 135, and 180 degrees of torsion 24 hours post-operation: 0.94 ± 0.07, 1.03 ± 0.15, 1.26 ± 0.22, 1.41 ± 0.11, and 0.89 ± 0.15 ml/min respectively.

Conclusion:

- Torsion of up to 180 degrees does not affect early vein graft patency in rat models.
- Suggestion to improve clinical reproducibility of practicing vein graft procedures in rat models:
  - Microsurgery instructors should assess vein graft torsion prior to clamp release

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Introduction

- Vein grafts are used to bridge vessel gaps in situations where primary vessel repair would result in excessive tension across the anastomosis.[1]
- Microsurgery training courses incorporated interpositional vein graft procedures, using femoral or epigastric veins as grafts, in their curricula to provide surgeons with clinically relevant models to practice these procedures in a controlled environment.
- At the Microsurgery Training and Research Laboratory of the Columbia University Irving Medical Center, it was found that torsion of the vein graft is a common technical error made by surgeons.
- The torsion was caused by misalignment of the proximal and distal anastomoses.
- Torsion of vein grafts is commonly cited as a reason for vascular thrombosis in medical literature and clinical case reports,[2-6] yet there was no data to suggest whether vein graft torsion would lead to thrombosis in a rat model.
- This study aimed to determine if vein graft torsion was a risk factor for vascular thrombosis in non-survival surgery rat models.

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Methodology

Preparation

- 5 sets of 5 Sprague-Dawley rats were divided into cohorts based on degree of vein graft torsion (0, 45, 90, 135, and 180 degrees).
- The mean weight of the rats was 414 g (range, 358-530 g).
- The rats were anesthetized with a combination of ketamine (70 mg/kg) and xylazine (5 mg/kg), and anesthesia was maintained via an intraperitoneal ketamine bolus.
- All surgeries were competed using a surgical operating microscope (Zeiss OPMI MD; Carl Zeiss; Jena, Germany) and 10-0 nylon sutures with a 135° taper (Surgical Specialties Corporation; Reading, PA).
- Heparinized saline was used to irrigate the vessels throughout the procedure, and 1% lidocaine solution was applied to relieve any vascular spasm.[7]

Preparing the artery

- An oblique incision was created along the inguinal fold to expose the femoral vessels.
- The inguinal fat pad was dissected and the femoral artery was identified.
- All branches were ligated, cauterized, and transected.
- Single vascular clamps were applied to the femoral artery near the inguinal ligament (proximally) and the superficial epigastric branch (distally).
- A defect was created in the artery at the midline between the clamps, and the vessel ends were irrigated with heparinized saline, trimmed for adventitia, and dilated.

Harvesting the vein graft

- Size-mismatch between graft and recipient vessel ends is a cited risk factor for vascular thrombosis.[8]
- To avoid this issue, the superficial epigastric vein was used for the graft as it diameter is similar to that of the femoral artery (approximately 1 mm in diameter).
- The epigastric vein was dissected, and 2 marking sutures were placed on the same linear segment on the vein's surface at a distance of 5.0 ± 0.5 mm from each other.
- The tail of the distal marking suture was left long to identify the distal end of the vein graft.
- 2 ligating sutures were placed
  - Near the superficial epigastric branch (proximally)
  - Near the inguinal fat pad (distally)
- The vein graft was then harvested and irrigated with heparinized saline, trimmed for adventitia, and dilated.
- All vein grafts were controlled to be 7.0 ± 0.5 mm in length

Completing the proximal anastomosis

- The anastomosis was completed with 8 circumferential sutures.[10]
- Stay sutures were initially placed at the 12 and 6 o'clock positions.
- A third suture was placed at the 3 o'clock position, and the tail of its suture was left long as a handle to place the 1:30 and 4:30 o'clock sutures.
- The vessel was then rotated, and the sixth suture was placed at the 9 o'clock position with its tail left long as a handle.
- The remaining sutures were then placed at the 7:30 and 10:30 o'clock positions to complete the anastomosis.

Twisting the vein graft at the distal anastomosis

- Torsion was created in the vein grafts at the distal arterial end by mismatching sutures placed between the proximal end of the vein graft and the distal arterial end (Fig. 1).
- For example, to create 90 degrees of torsion, the suture placed at the 12 o'clock position on the proximal end of the vein graft would connect with the 3 o'clock position on the distal arterial end (Fig. 2).
- The next suture placed connected the 6 o'clock position on the proximal end of the vein graft with the 9 o'clock position on the distal arterial end.
- The other 6 interrupted circumferential sutures would then be placed as described by Cooley to complete the anastomosis.[10]
- Torsion was verified by noting the misalignment of the marking sutures on the vein graft before releasing the clamps (Fig. 3) and by any evidence of torsion dispersing to the arterial ends after releasing the clamps (Fig. 4).

Verifying patency

- After completing both the proximal and distal anastomoses and removing the clamps, the inguinal fat pad was placed over the vein graft for hemostasis for 2 minutes.
- Patency was verified 2 and 24 hours post-operation via 2 techniques—transit-time ultrasound blood flow measurements and the empty-and-refill test.[11]
- *Blood flow measurements*: Flow probes were placed under the distal arterial end (Fig. 5), and measurements averaging blood flow rates over 8 seconds were recorded (Fig. 6).
- *Empty-and-refill test*: 2 straight edge jeweler's forceps were placed adjacent to the distal anastomosis on the distal arterial end and used to occlude the vessel. While occluding the vessel, the forceps further from the anastomosis were transposed distally along the vessel to milk the artery, leaving a segment of empty artery between the two forceps. The forceps closer to the anastomosis were then released, allowing blood to refill the empty artery if the anastomosis was patent.

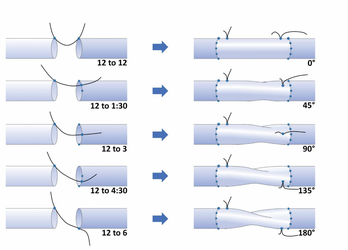

Fig 1. Left column: diagram of mismatched stitches

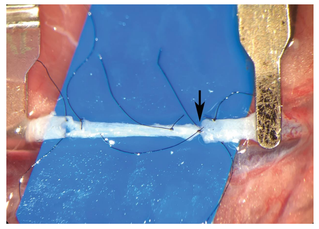

Fig 2. Vein graft with 90 degrees of torsion

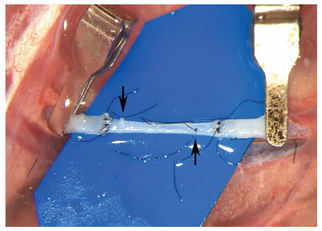

Fig 3. Completed vein graft with 90 degrees of torsion, before releasing clamps

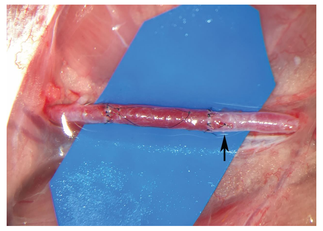

Fig 4. Completed vein graft with 90 degrees of torsion, after releasing clamps

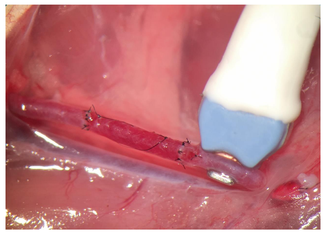

Fig 5. Verifying vein graft patency with transit-time ultrasound blood flow measurements

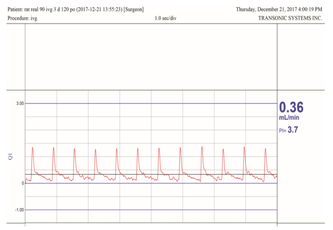

Fig 6. Blood flow rate graph recorded 2 hours post-operation for a completed vein graft with 90 degrees of torsion

Results

- All vein grafts were patent 2 and 24 hours post-operation.

Average blood flow measurement rate (2 hours)	
Torsion (degrees)	Average blood flow rate (mL/min)
0	0.37 ± 0.02
45	0.38 ± 0.04
90	0.34 ± 0.01
135	0.33 ± 0.01
180	0.29 ± 0.02

Average blood flow measurement rate (24 hours)	
Torsion (degrees)	Average blood flow rate (mL/min)
0	0.94 ± 0.07
45	1.03 ± 0.15
90	1.26 ± 0.22
135	1.41 ± 0.11
180	0.29 ± 0.02

Discussion & Conclusion

- Torsion of up to 180 degrees does not affect early vein graft patency in rat models.
- In human patients, it is common to minimize dissection to reduce tissue damage and the potential of scarring, yet for interpositional vein graft exercises in rat models, the entire femoral artery is dissected, which significantly mobilizes the artery.
- Torsion becomes widely distributed along the graft and artery and is quite difficult to appreciate visually.
- Torsion is a potential risk factor for vascular thrombosis in the clinical setting.
- To improve the clinical reproducibility of practicing vein graft procedures in rat models, we suggest that instructors of microsurgery training courses assess the success of a completed vein graft not only on patency but also on the basis of any torsion in the vein graft prior to clamp release.

Acknowledgements

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