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IDEAS AND INNOVATIONS

Reconstructive

Intimal Surface Suture Line (End-Product) Assessment of End-to-Side Microvascular Anastomosis

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Summary: Microsurgery simulation courses increasingly use assessment methodologies to evaluate the quality of microvascular anastomosis and to provide constructive feedback in competency-based training. Assessment tools evaluating the "journey" of skill acquisition in anastomosis have evolved, including global rating scores, hand motion analysis, and evaluation of the final outcome, that is, "end-product" assessment. Anastomotic patency is the gold standard end-product in clinical microvascular surgery, and in vivo end-to-side anastomosis, which can be confirmed using the Acland-test. Microsurgery simulation training is moving to include nonliving models, where possible, according to the principles of the replacement, reduction, and refinement of the use of animals in research. While a standardized end-product assessment tool for nonliving end-to-end anastomosis exists, there is no similar tool for end-to-side anastomosis. Intimal surface suture line assessment is an error list-based tool, which involves exposing the intimal surface of a vessel and analysis of the quality of suture placement. Errors in end-to side anastomosis were classified according to the potential clinical significance (high, medium, or low) perceived by the senior authors. Intimal surface suture line assessment provides constructive feedback during microsurgery training, helping to minimize technical errors, which are likely to impact on the final outcome in a clinical environment. Intimal surface suture line assessment lends itself to nonliving simulation training courses as an end-product self-assessment tool, especially during the early learning curve, to demonstrate progression. It has intraoperative relevance by assessment of the intimal surface suture line as the final sutures are placed in an end-to-side anastomosis to provide objective feedback to trainees in relation to likely physiological anastomotic outcome. *(Plast Reconstr Surg Glob Open 2017;5:e1409; doi: 10.1097/GOX.0000000000001409; Published online 24 July 2017.)*

End-product assessment tools are increasingly incorporated in simulation courses to evaluate the quality of the microvascular anastomosis and to track learning curve progression in early microsurgery training. The first steps in microsurgery skills acquisition are achieved using simulation models, based either on nonbiological materials or tissue, which can be living or nonliving. There is current a trend toward the use of nonliving models, to further the ethical principle of replacement, reduction, and refinement (3Rs) animal use.[1]

A surgeon's "journey" in completing a microvascular anastomosis can be objectively assessed using global rating scales and hand motion analysis, which are valid and reliable methodologies that could improve progression in skills acquisition.[2] Assessment of the final outcome of end-to-end anastomosis during a 5-day nonliving microsurgery training course demonstrated the construct and predictive validity of the anastomosis lapse index (ALI).[3]

The gold standard outcome in microvascular surgery is anastomotic functional patency. Immediate patency of an end-to-end anastomosis with physiological flow can be confirmed in vivo and subjectively using the flicker/Acland test or the double occlusion test.

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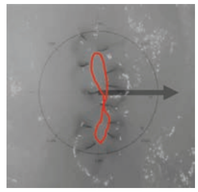
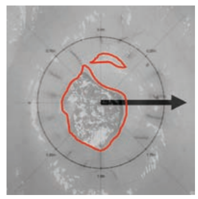
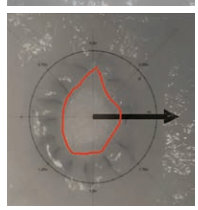
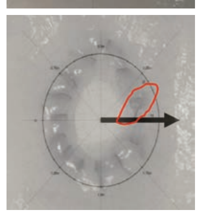
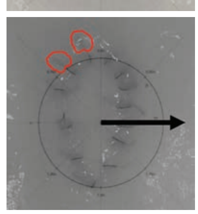
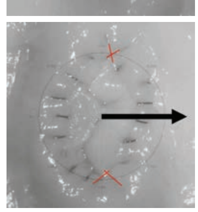
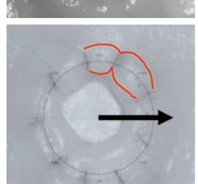
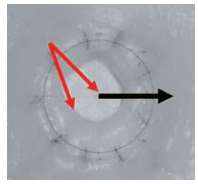
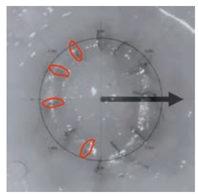
Table 1. ISSLA Error List for End-to-Side Anastomosis

Error in End-to-Side Anastomosis	Clinical Impact on Patency	Intimal Suture Line Photograph	Constructive Feedback
Back-wall stitch	High		A lack of precision while driving the needle transverse to the recipient vessel could form a narrow or nonpatent lumen due to the tendency of the arteriotomy walls to collapse in this plane.
Side-wall stitch	High		A lack of precision while driving the needle longitudinal to the recipient vessel could form a restricted anastomosis opening through the edges of the arteriotomy.
Uneven lumen	High		Unevenly placed sutures could form a lumen with an oval-, slit, or diamond shape, which may disrupt flow through the lumen.
"Moustache" suture	Medium		Cutting the suture to leave a long tail could cause the suture tail to displace in the lumen. In vivo this would result in turbulent flow.
"Cheese-wire tear"	Medium		This can be caused by: (1) placement of a tight suture, and, (2) driving the needle without following its curvature. In vivo this would cause anastomotic bleeding.
Large "quilting" bite	Medium		This can be caused by: (1) a loose securing knot while suturing, and, (2) applying uneven hand forces during knot tying. In vivo this would cause an uneven lumen, and potentially, turbulent flow.
Edge-crossed "x" sutures	Low		Driving the needle through the edges of the arteriotomy could form edge-crossed sutures, causing vessel wall strangulation.
Strangulation of tissue	Low		This can be caused by: (1) a tight securing knot while suturing, and, (2) applying uneven hand forces during knot tying, causing flow disturbance.

(*Continued*)

Table 1. ISSLA Error List for End-to-Side Anastomosis

Error in End-to-Side Anastomosis	Clinical Impact on Patency	Intimal Suture Line Photograph	Constructive Feedback
Non-radial orientated suture	Low		This can be caused by: (1) wrong positioning of the hands, or, (2) erroneous handling of the instruments, when placing the needle through the vessel wall.
Partial-thickness bite	Low		This can be caused by: (1) inadequate opposition during counter traction, or, (2) inadequate perpendicular placement of the needle, during a vessel-wall bite. This would cause inadequate apposition of the intimal surface of the vessel wall.

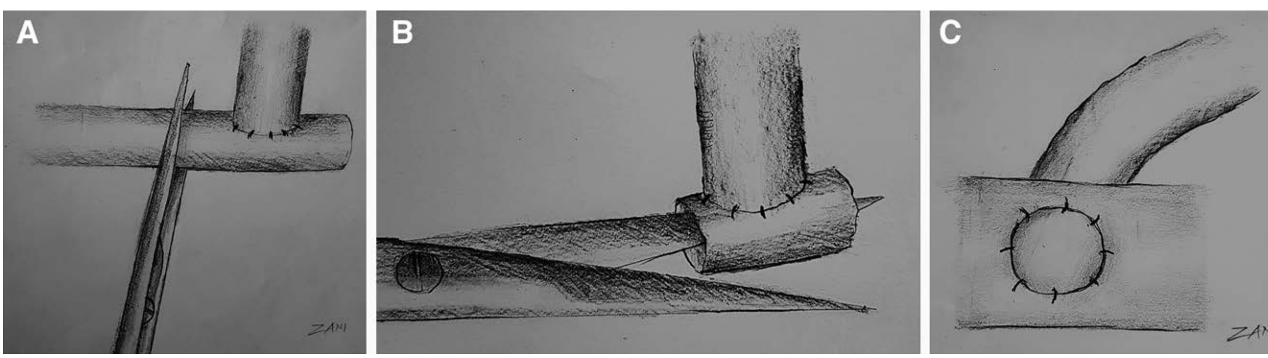


Fig. 1. Illustration of methodology steps for intimal surface suture line assessment: 2 transverse cuts before and after an end-to-side anastomosis (A), a longitudinal cut on the opposite vessel wall to expose the intimal surface of the suture line (B), flattening this to reveal the intimal surface of both the end-wall vessel and the side-wall vessel, revealing the micro-loops piercing both vessel walls in each suture (C).

Evidence for an end-to-end against an end-to-side approach in relation to clinical outcome remains unclear. Cho et al.[4] compared outcomes following lower extremity reconstruction using either the end-to-end or end-to-side techniques and found no difference in outcomes. End-to-side anastomosis objective assessment tools are required.

We expand the scope of structural patency assessment tools by proposing the intimal surface suture line assessment (ISSLA) as an end-product assessment of end-to-side anastomosis. An error list was built on trainer observations of a 5-day nonliving microsurgery training course between 2014 and 2017. The most frequent errors for end-to-side anastomosis have been classified into 3 groups according to the clinical severity of their impact on patency: high, (1) back-wall stitch, (2) side-wall stitch, and, (3) uneven shape (oval-, slit-, or diamond-shaped); medium, (4) "moustache" suture tail within lumen, (5) "cheese-wire tear" (tight suture), (6) large "quilting" bite (loose suture), and, low (7) edge-crossed "x" sutures; low, (8) strangulation of tissue (tight suture), (9) nonradial orientated suture, and, (10) partial-thickness bite. ISSLA can be incorporated into microsurgery training courses using nonliving models as a constructive feedback tool, similar to the ALI score[3] (Table 1). Assessing the end-product offers a means to evaluate progression, and by eliminating or minimizing errors that may lead to patency failures, improve progress along the early learning curve. Such an end-product assessment can provide holistic, objective self-assessment feedback. Pilot experience using the ISSLA score demonstrated that novice surgeons after 40 hours of practicing, at least 20 end-to-end and end-to-side anastomosis and completing the 5-day nonliving microsurgery course eliminate high impact errors. ISSLA offers a subjective classification of each error in 3 categories based on the expected structural patency reflected. Our experience demonstrates that initial steps in microvascular anastomosis training should focus on the precision while driving the needle through the vessels wall, with adequate accuracy, counter-traction, and safety checks, to avoid high impact on patency errors. However, the predictive clinical impact of each error is not based on structured data collection to address the frequency and occurrence of each error on the early microsurgical training learning curve. Therefore, a detailed demonstration of each error and the constructive feedback able to be generated when it is utilized in end-to-side microvascular training are substantial. The ALI score and ISSLA can be validated to predict the anastomotic patency by correlating their performance of training microsurgeons on nonliving models with the physiological patency in living animal models and support the 3Rs in microsurgery training. The methodology is simple and similar to the ALI score. Two transverse cuts are made either side of an end-to-side anastomosis, and a longitudinal cut on the opposite vessel wall exposes the intimal surface of the suture line (Fig. 1). Laying this flat reveals the intimal surfaces of both the end-wall vessel and the side-wall vessel and the "micro-loop" piercing both vessel walls of each suture. Schubert et al.[5] established that vessel endothelial injury and intimal hyperplasia occur following traumatic needle insertion during simple interrupted sutures, potentially contributing to poor arterial flow. Onoda et al.[6] demonstrated that failure of supermicrosurgery lymphaticovenous anastomosis is principally related to endothelial layer misalignment, leading to exposure of the subendothelial layers and directly related to technical errors.

The clinical application of the ALI score and ISSLA is self-evident. Occasionally, an anastomosis could be checked intraoperatively, before the last few suture placements through the incomplete wall opening, and at that point it may be possible to identify the technical cause of the potential failure using such tools. Surgical mentors can be encouraged to provide objective feedback to their trainees and avoid erroneous suture placement.

End-product assessment of the structural patency of end-to-side anastomosis (ISSLA) in nonliving microsurgery training has proven to be simple and will expand the established predictive and construct validity of end-to-end anastomosis using the ALI score, facilitating microsurgical training, and providing invaluable feedback when technical failures occur.

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