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Intravascular Stenting in Microvascular Anastomoses

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Abstract

Background  The effect of intravascular stenting (IVaS) on microvascular anastomoses has given adverse results. For experienced microsurgeons the benefit of IVaS is doubtful. We have investigated the potential benefit of the IVaS technique for two groups of inexperienced microsurgeons with different surgical levels of experience (medical students and young residents). Experienced microsurgeons acted as a control group.

Materials and Methods  In an experimental crossover study, 139 microsurgical anastomoses were performed on the femoral artery in 70 rats by 10 surgeons. On one side of the rat, the IVaS technique was used. A small piece of 5–0 nylon monofilament was placed in the vessel lumen, acting as a temporary stent during microvascular anastomosis. A conventional technique without the stent was performed on the other side. Patency rates of the vessels in each group were compared as well as the time spent on the anastomosis.

Results  No significant difference in patency rates was seen between the stenting and conventional technique in all three groups. The experienced microsurgeons had 100% patency rate with both techniques. The medical students had 20/28 in the IVaS and 19/28 conventional group and the patency rates for the residents were 23/27 using IVaS and 23/28 using the conventional technique. The residents were faster using the IVaS whereas the students and experienced microsurgeons were faster without the stent.

Conclusion  The IVaS technique did not seem to benefit either the inexperienced or experienced microsurgeons regardless of their clinical experience. The study also shows that some surgical experience seems to be an advantage in performing microsurgery.

The advent of microvascular surgery during the last century has resulted in revolutionary advances for the reconstructive surgeon.1 It is used extensively in many different areas such as free flap surgery, replantations,2 and lymphaticovenous anastomoses.3 The technique has evolved to a level where vessels less than 1 mm in diameter are now being anastomosed with great success.

Microsurgery still remains a technically challenging procedure, even for the skilled surgeons. Failure rates, however, are strongly related to experience4 and technique.5 Training of novice microsurgeons is therefore of utmost importance.

Technical pitfalls such as inadvertently catching the posterior wall, uneven suture spacing, and poor vessel wall apposition causes thrombosis and possible failure.

Attempts have been made to overcome these problems. Some of them include the temporary stenting technique; first described by Wei et al in 1982.6 They used a silastic tube as a temporary stent in a rat femoral vein. A slight increase in the patency rate was found in the stenting group. The use of a nylon monofilament as stent has also been explored,7–10 claiming that it is more accessible and easier to adjust the size of the stent to the vessels. It has been named the intravascular stenting (IVaS) technique by Narushima et al.7

The effect of intravascular stenting (IVaS) on microvascular anastomoses has given adverse results. For experienced microsurgeons the benefit of IVaS is doubtful. We have investigated the potential benefit of the IVaS technique for two groups of inexperienced microsurgeons with different surgical levels of experience (medical students and young residents). Experienced microsurgeons acted as a control group. In an experimental crossover study, 139 microsurgical anastomoses were performed on the femoral artery in 70 rats by 10 surgeons. On one side of the rat, the IVaS technique was used. A small piece of 5–0 nylon monofilament was placed in the vessel lumen, acting as a temporary stent during microvascular anastomosis. A conventional technique without the stent was performed on the other side. Patency rates of the vessels in each group were compared as well as the time spent on the anastomosis.

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The IVaS technique did not seem to benefit either the inexperienced or experienced microsurgeons regardless of their clinical experience. The study also shows that some surgical experience seems to be an advantage in performing microsurgery.

References


Keywords
microsurgery
intravascular stenting
IVaS

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The general hypothesis in the literature is that the stent produces a visible lumen, which helps with the aforementioned pitfalls. Moreover, it makes forceps dilatation of the vessel unnecessary, thereby preventing intimal damage.

The effect of IVaS on microvascular anastomoses has given adverse results (~Table 1). The benefit to the experienced microsurgeon is doubtful,7,8 but there are suggestions that the IVaS technique can be useful for less-skilled microsurgeons10 or for extremely small vessels, such as the mouse superficial inferior epigastric artery.7

This study aims to investigate the potential benefit of IVaS to the inexperienced microsurgeons when practicing microsurgery. The studies performed so far have not elaborated on the level of experience; we therefore included three groups of surgeons in the study as follows: (1) medical students with no surgical experience and (2) young residents with previous surgical experience, both without any microsurgical experience, and (3) the third group, acting as a control group, consisted of experienced microsurgeons.

The study was performed as an experimental crossover study on the rat femoral artery. The IVaS technique was used on one side of the rat and the conventional technique on the other side. The patency of the Anastomosed vessels was compared according to the technique and level of experience.

Materials and Methods

A total of 70 healthy male Sprague-Dawley rats were used for the study.

The rats weighing between 220 and 390 g were anesthetized with a combination of hypnorm (fentanyl 0.315 mg/mL and fluanosine 10 mg/mL), midazolam 5 mg/mL, and sterile saline in the ratio of 1:1:2. An initial dose of 0.3 mL/100 g body weight was given subcutaneously, followed by a maintenance dose of 0.1 mL/100 g body weight approximately every hour. The rats were given approximately 3 mL of saline subcutaneously before the surgery to compensate for blood and fluid loss. The rats were laid on a heating pad throughout the surgery.

The rats were shaved in the groin region and an incision was made across the inguinal canal. The femoral vessels were exposed and dissected and a piece of background material was placed under the femoral artery. The clamps were applied and the vessels transected using a microsurgical scissor. A slight adventectomy was performed; the lumen was washed with a heparin solution (50 IU/mL) and the vessel ends dilated with jewelers forceps.

Crossover

The experiment was performed by 10 different surgeons: 4 medical students with no surgical experience, 4 young residents with an average of 5 years of surgical experience, but with no microsurgical training, and experienced microsurgeons with several years of microsurgical experience. The inexperienced groups received a short, intensive microsurgical course. A slight adventectomy was performed; the lumen washed with a heparin solution (50 IU/mL) and the vessel ends dilated with jewelers forceps.

Conventional Technique

The anastomoses were performed using a 10–0 nylon monofilament suture. Two stay sutures were placed approximately

### Table 1: Previous studies examining the intravascular stenting technique in rats

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Stent size</th>
<th>Vessel</th>
<th>Surgeon</th>
<th>Results (Patency)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bossut et al10</td>
<td>2011</td>
<td>4–0</td>
<td>Femoral artery</td>
<td>4 mo of experience</td>
<td>Conventional: 5 min: 100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 h: 94.4%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 wk: 83.3%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stent: 5 min: 100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 h: 88.8%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 wk: 83.3%</td>
</tr>
<tr>
<td>Miyamoto et al8</td>
<td>2010</td>
<td>5–0</td>
<td>Superficial inferior epigastric artery</td>
<td>Experienced surgeon</td>
<td>100% in all categories</td>
</tr>
<tr>
<td>Narushima et al7</td>
<td>2008</td>
<td>4–0</td>
<td>Superficial inferior epigastric artery</td>
<td>–</td>
<td>Conventional: Immediate: 80%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 wk: 60%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stent: Immediate: 80%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 wk: 60%</td>
</tr>
<tr>
<td>Chaware et al9</td>
<td>2006</td>
<td>6–0</td>
<td>Femoral artery</td>
<td>–</td>
<td>Conventional: 19/27 (70.4%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stent: 25/27 (92.6%)</td>
</tr>
</tbody>
</table>

*Results are statistically significant.
160 degrees apart. One or two sutures were placed in the middle and the vessel was turned over. On the other side two to four sutures were placed.

Records were obtained of the time spent, from when the first suture was ready to be set until completion of the anastomosis.

Temporary Stent Technique
Blue pieces of 5–0 nylon monofilaments were used as stents. The length of the stents was equal to the width of the gap between the free end of the vessel and the clamp, as described by Narushima et al.\(^7\). The stent was cut into the right size with a sharp surgical knife, leaving no sharp ends to damage the vessel lumen.

Before the first suture being placed, the stent was inserted into the artery. It was first inserted on one side of the artery. The clamps were moved closer together and half of the stent was inserted into the other side of the artery (► Figs. 1 and 2A–E). The anastomosis was completed similar to the conventional technique, but the last suture was left untied and tied after the stent was removed.

Records were obtained of the time spent, from when the stent was ready to be inserted until completion of the anastomosis.

Approximately 4 to 9 sutures were sufficient for all 139 anastomoses (experienced microsurgeons: 4–6 sutures; inexperienced microsurgeons 5–9 sutures).

The distal clamp was removed first and after backfilling was noted, the proximal clamp was removed. Distal pulsation was noted as a sign of patency,\(^11\) and the refill patency test as described by Hayhurst and O’Brien\(^12\) was performed after 30 minutes.

The rats were euthanized with an overdose of pentobarbital after completion of the operations while the rats were still sedated.

The study was approved by the Danish National Animal Experimental Board and the animals were housed in approved facilities.

Statistical Analysis
The patency of the two groups was compared using Fisher exact test and the anastomosis time of the two groups were compared using a two-sample independent t-test. Values of \(p < 0.05\) were considered statistically significant in each analysis. Openepi.com was used as software program.

Results
Patency
The medical students had a patency rate of 20/28 when using the stent. Without the stent the patency was 19/28, giving a \(p\)-value > 0.99 (► Table 2).

The residents results were 23/27 and 23/28 with and without the stent, respectively. This gives a \(p\)-value of > 0.99. One rat died during surgery in the stenting group and is therefore not included.

We also compared the medical students and the residents’ patency results. Overall the residents group had better patency rates: 20/28 in the medical students’ stenting group as compared with 23/27 in the residents’ stenting group (without stent 19/28 and 23/28, respectively). None of the results were statistically significant (► Table 3). The overall patency rate for the medical students were 39/56 and 46/55 for the residents, giving a \(p\)-value of 0.13.

The experienced microsurgeons had a patency rate of 100% in both the groups.

The difference between the experienced microsurgeons patency results and the students were statistically significant.
without stent \( (p = 0.03) \) but not with stent (Table 4). The difference between the experienced microsurgeons and the residents was not statistically significant (Table 5).

**Time Measurements**
There were large variation in the time spent on performing the anastomoses for the medical students and the residents.

The medical students were performing the anastomoses faster with the stent; mean time 34.43 minutes compared with 30.16 minutes with the conventional technique. This gives a \( p \)-value of 0.14.

The residents’ mean times were 30.69 with stent and 31.67 minutes, respectively, with the conventional technique, giving a \( p \)-value of 0.76.

The experienced microsurgeons were performing the anastomoses faster without the stent. The difference was not statistically significant \( (p = 0.12, \text{ Table 6}) \).

The experienced microsurgeons were faster than both the medical students and the residents performing the anastomoses both with and without stent. The difference was statistically significant in all cases \( (p < 0.05) \).

**Discussion**

The experienced microsurgeons had, as expected, 100% patency rate in both the groups. This confirms the results of previous studies\(^7,8\); that the benefit of the stenting technique is doubtful for the experienced microsurgeons. They were

<table>
<thead>
<tr>
<th>Table 2 Patency test</th>
<th>Positive patency test (%)</th>
<th>Positive patency test (%)</th>
<th>( p )-Value</th>
<th>Positive patency test (%) in total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>stent</td>
<td>conventional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical students ((n = 56))</td>
<td>20/28 (71.4)</td>
<td>19/28 (67.9)</td>
<td>&gt; 0.99</td>
<td>39/56 (69.6)</td>
</tr>
<tr>
<td>Residents ((n = 55))</td>
<td>23/27(^a) (85.2)</td>
<td>23/28 (82.1)</td>
<td>&gt; 0.99</td>
<td>46/55 (83.6)</td>
</tr>
<tr>
<td>Experienced microsurgeons</td>
<td>14/14 (100)</td>
<td>14/14 (100)</td>
<td>&gt; 0.99</td>
<td>28/28 (100)</td>
</tr>
</tbody>
</table>

\(^a\)One rat died during surgery.
also, as expected, faster than both the residents and the students.

The surgeons with no microsurgical experience had failures. The patency failures were all due to thrombosis. A short segment of the vessel at the site of the anastomosis were excised and inspected in the microscope. It was not possible to identify the cause of thrombosis in any of the cases. None of the failures (as seen in the excised piece) were caused by inadvertently catching of the back wall. In two cases the stent was left behind and the anastomosis had to be reopened to remove the stent, both the cases thrombosed.

Several studies have demonstrated that anastomoses failures occur primarily in the first 24 hours. Bossut and Barbier have shown that further 5 to 11% of anastomoses failures in the femoral artery occur from 1 hour to 1 week. We only tested the immediate patency rate as we already had a significant number of failures and because the study was an experimental crossover we would expect that the number of further failures in the two groups would decline in a similar fashion and would be small (within a range of 10%).

Other causes were most likely poor vessel wall apposition, poor suture tension, or uneven suture spacing. Overmanipulation of the stent in the IVaS group could also have caused thrombosis due to intimal damage, although previous studies have demonstrated that the stent does not cause damage to the endothelia.

Different reports have given suggestions to the size of the stent. Narushima et al recommends that the diameter of the stent is coupled to the vessel size. We used a standard 5–0 nylon monofilament as a stent. Following the recommendations of Narushima et al, we should have used a larger stent although Chaware et al used a 6–0 nylon monofilament for the femoral artery with good results.

The length of the stent can also be discussed. Bossut and Barbier made the stent a bit longer claiming that it fell out too easily. They had to open the distal clamp to get the stent out and then tie the last suture, which was done during poor visualization because the lumen was filled with blood.

We did not make our stent longer and the stent did fall out occasionally. The problem was solved after the first stay suture was set.

The handling of the stent during insertion and retraction of the stent is often thought as being traumatizing to the endothelia and a potential cause of thrombosis. Chaware et al performed anastomosis on the rat femoral artery and examined both the anastomotic site and the area between the anastomotic site and the clamp with an electron microscope. They found that the stent made less damage to the endothelia

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Comparing the inexperienced microsurgeons, patency test</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Medical students</td>
</tr>
<tr>
<td>Positive patency test (%), stent</td>
<td>20/28 (71.4)</td>
</tr>
<tr>
<td>Positive patency test (%), conventional</td>
<td>19/28 (67.9)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Comparing the students and the experienced microsurgeons, patency test</th>
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<tbody>
<tr>
<td></td>
<td>Experienced microsurgeons</td>
</tr>
<tr>
<td>Positive patency test (%), stent</td>
<td>14/14 (100)</td>
</tr>
<tr>
<td>Positive patency test (%), conventional</td>
<td>14/14 (100)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 5</th>
<th>Comparing the residents and the experienced microsurgeons, patency test</th>
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<tbody>
<tr>
<td></td>
<td>Experienced microsurgeons</td>
</tr>
<tr>
<td>Positive patency test (%), stent</td>
<td>14/14 (100)</td>
</tr>
<tr>
<td>Positive patency test (%), conventional</td>
<td>14/14 (100)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 6</th>
<th>Duration of the anastomosis</th>
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<tbody>
<tr>
<td></td>
<td>Mean time (min)</td>
</tr>
<tr>
<td></td>
<td>stent</td>
</tr>
<tr>
<td>Medical students</td>
<td>34.4</td>
</tr>
<tr>
<td>Residents</td>
<td>30.7</td>
</tr>
<tr>
<td>Experienced microsurgeons</td>
<td>19.7</td>
</tr>
</tbody>
</table>
than dilatation with forceps. The vessel ends of the IVaS group were not dilated with forceps. This can be a confounder. Some of the other studies\(^1\) also did not dilate the vessel ends in the IVaS group.

Narushima et al\(^7\), who used a stent with a larger diameter than Chaware et al, also examined the endothelia with an electron microscope and found the vessels smooth and free of injury. Careful handling of the stent is mandatory to avoid traumatization of the endothelia.

Handling of the stent was a problem for both the groups. Microsurgical experience is certainly an advantage when small stents have to be handled under a microscope.\(^8\)

The anastomosis in our study, were not examined with an electron microscope and we can therefore only speculate if the handling of the stent contributed to the failures in the IVaS group.

The eight inexperienced surgeons in the study had different degrees of surgical training. The medical students were clinically inexperienced and had no previous surgical training, whereas the residents had a minimum of 4 and an average of 5 years of clinical and surgical experience. Both participants received a short intensive course in microsurgery, practicing on the PVC (Braintree Scientific Inc., Braintree, MA) rat\(^1^3\) and on live rats. The experienced microsurgeons had over 10 years of experience.

The residents had 85.2% patency rate in the IVaS group compared with 82.1% in the conventional group; the patency rate was not statistically significant \((p > 0.99)\).

The difference in patency rate in the IVaS group compared with the conventional technique for the medical student group was also not statistically significant \((p > 0.99)\).

From a formal scientific point of view, it could be argued that this study is underpowered to see an effect of the IVaS technique. Apposed hoc power analysis confirms this, but as in many experimental studies the number of experimental animals that were needed to obtain sufficient power could not be justified as very little suggested that stenting was beneficial to either group.

The IVaS technique seems to have little or no benefit to the microsurgical inexperienced or experienced surgeon regardless of the level of clinical or surgical experience. It further gives rise to a great deal of frustration, especially to the inexperienced microsurgeons.

The surgeons all agreed that there were more disadvantages than advantages in using the stent. The advantages were described as better visualization of the lumen by all surgeons. The suture spacing and vessel wall apposition was not described as being easier with the IVaS technique.

The stent falling out easily was the biggest disadvantage, described by the inexperienced microsurgeons. As described earlier, the problem was solved after the first or second stay suture was placed. The retraction of the stent was described as a problem to all groups. The surgeons felt that it could traumatize the endothelia. Insertion of the stent was not a problem and all the inexperienced microsurgeons agreed that a stent with a larger diameter could have been an advantage. The experienced microsurgeons found the stent too rigid, but the diameter of the stent suitable. They felt that the stent could be an advantage in smaller vessels and anastomoses of veins.

For the inexperienced microsurgeons previous surgical training and clinical experience seem to be an advantage in performing microsurgery. The residents had 14% better patency rates than the medical students \((83.6\) vs. \(69.6\), respectively), but it was not statistically significant \((p = 0.13)\). If a larger number of experimental animals had been included the difference would most likely be significant.

**Conclusion**

The IVaS technique does not seem to be an advantage regardless of level of surgical and clinical experience. The use of IVaS in the training of the inexperienced microsurgeon is therefore questionable and the technique is also not recommendable for the experienced microsurgeons.

Previous surgical and clinical experience seems to be an advantage for the inexperienced microsurgeons, but it is not statistically significant. The study also shows that a short intensive course can result in acceptable patency rates even for the surgical novice, although better results come with more surgical training.

**References**