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ORIGINAL ARTICLE

Loop ligation: objective assessment of surgical efficiency in vessel ligation with electromagnetic hand motion analysis

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Abstract

Background: Vessel ligation is a common technique within many surgical specialties. We present the loop vessel ligation technique and compare it with the conventional vessel hand-tie technique. **Methods:** Two surgeons performed vessel ligations using both loop vessel ligation and the conventional two-suture ligation technique. Hand motion analysis data were collected using the Dextrous MD electromagnetic device. Parameters including total path length (TP), total movements (TM) and total time (TT) were calculated to allow comparison of the techniques. An overall surgical performance (OSP) indicator was generated to reflect the collective effect of all variables. **Results:** Twenty vessel ligations were performed using both techniques. TP, TM and TT taken to complete a vessel ligation were all significantly improved with the loop vessel ligation technique ($P < 0.0001$). The OSP score was significantly better using the loop vessel ligation technique ($P < 0.0001$). **Conclusion:** Using electromagnetic hand motion analysis, this study objectively demonstrates that the loop vessel ligation technique significantly improves surgical performance for vessel ligation.

Keywords: *vessel ligation; hand-tie vessel; loop ligation; surgical efficiency; hand motion analysis*

Introduction

Suture vessel ligation is a common task within many surgical settings. Surgical ligation can be challenging and time consuming, especially when ligation of multiple structures or ligation of vessels in cavities are required or when instruments allow limited maneuverability. After using the simple technique of loop vessel ligation within a microsurgical simulation setting, we have revisited this method within a clinical setting and find it transferrable across surgical subspecialties, including vascular surgery and microsurgery.

We hypothesise that the loop vessel ligation technique can improve operative performance through improved economy of movement, while still achieving effective results. The aim of this study is to evaluate the surgical performance of loop vessel ligation versus the conventional double-suture ligation technique with electromagnetic hand motion analysis.

Materials and methods

Two right-handed plastic surgery specialty registrar surgeons were recruited for the study. Both surgeons performed vessel ligations using both loop vessel ligation and the conventional two-suture ligation technique. The objective in each task was to produce a sound knot that would be acceptable clinically. Surgeons were allowed to redo any aspect of the knot during the task, but data collection was continuous. The tasks were performed using a simulated silicon 2-mm vessel, a haemostatic clip, suture scissors and a 3/0 Vicryl suture (Fig. 1). The two techniques were performed 10 times alternatively from a randomised starting point determined using electronic random selection. All tasks were performed in a single sitting.

Hand motion analysis was performed with four sensors: one on the dorsum of each hand across the second metacarpophalangeal joint, and one on the dorsum of each index finger middle phalanx (Fig. 2). An electromagnetic field of 72 cm in diameter was generated and Dextrous MD software (Inition, London, UK) processed each sensor's Cartesian coordinates (x, y, z) during each ligation repetition. Tasks were completed after baseline hand motion analyser calibration using a 30-cm ruler scale. Data were collected and the total path length (TP), total movements (TM) and total time (TT) were calculated. All

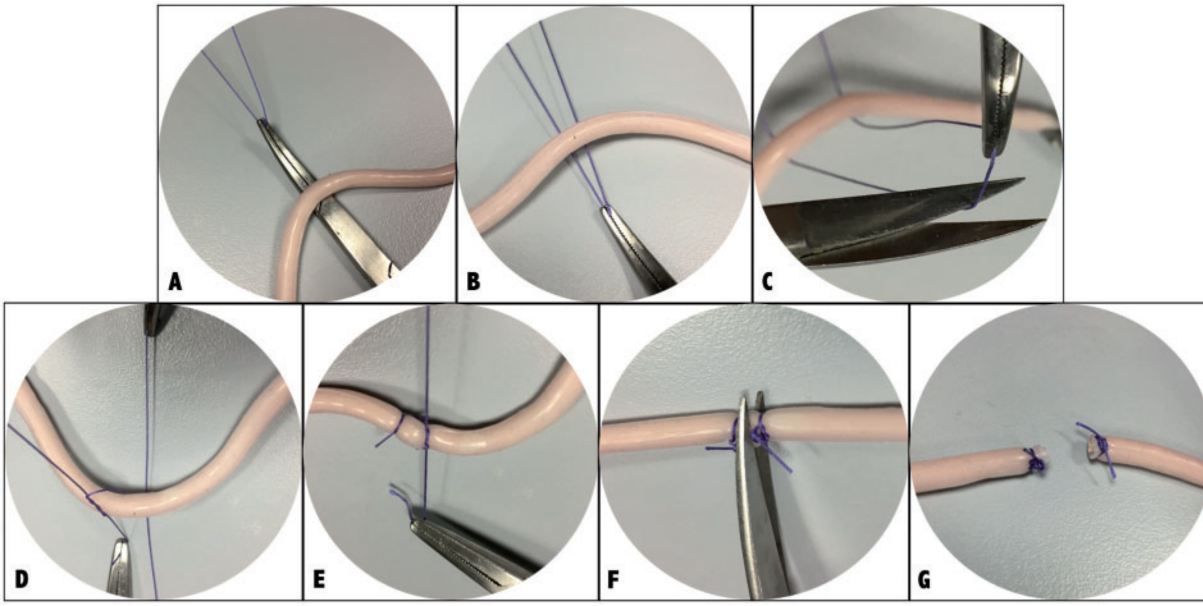

Figure 1. Loop ligation technique: (A, B) Pass a looped suture under the vessel in question; (C) cut the loop of the suture to form two individual threads; (D, E) tie both sutures in turn to ligate the vessel; (F, G) cut the vessel while maintaining an adequate suture ligation (in a clinical setting sufficient vessel length must be maintained between ties to prevent the knots slipping).

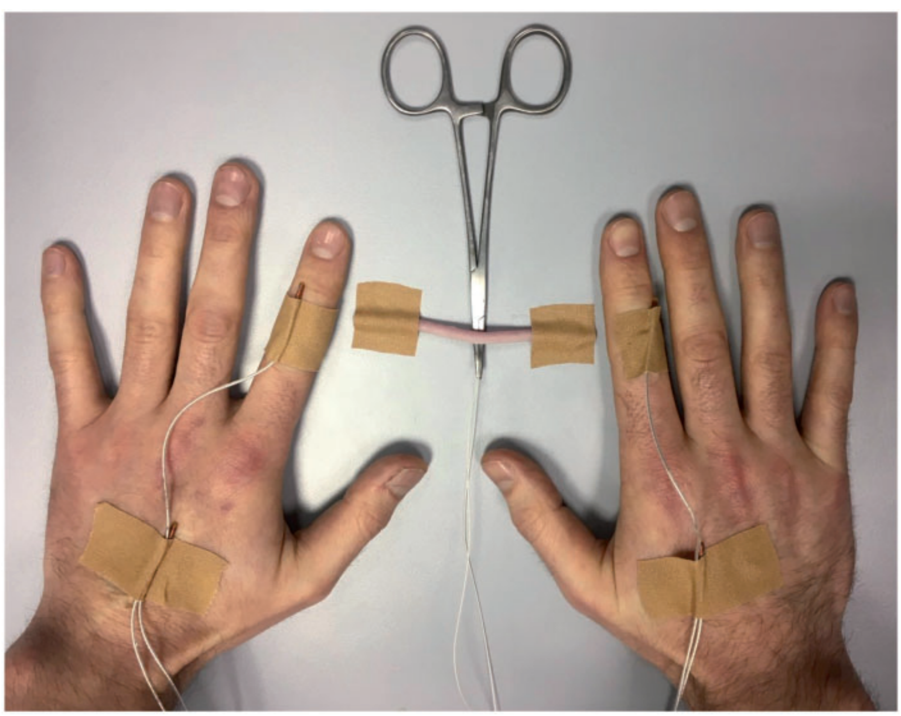

Figure 2. Electromagnetic hand motion analysis set-up/sensors.

data were collected using the same instrumentation and vessel material. Data were coded and analysed after all tasks were completed by an independent blinded investigator.

A performance indicator was generated to reflect the overall surgical performance: OSP = TT (seconds) + TM (number of movements) + (TP) (metres). Data were modified to allow comparison: (OSP = TT + TM/10 + TP/100).

Statistical analysis was conducted using GraphPad Prism version 7.0. Data are expressed as means ± standard error of the mean (SEM). An independent-sample t test for each individual parameter and collectively for overall surgical performance was used. A P value <0.05 was considered statistically significant.

The loop vessel ligation technique

Conventionally, a vessel ligation is performed by undermining the targeted vessel, clamping the targeted vessel proximally and distally and a suture is passed around to allow interrupted suture ligation on each side. This technique is performed twice for each single vessel ligation.

To perform a loop vessel ligation, the targeted vessel is clamped proximally and distally. A long suture is then looped and passed under the vessel and between the clamps. The looped end is cut allowing two individual threads to be aligned with the clamps. Each can then be tied in turn, either by hand or instrument, to achieve a safe and effective ligation (Fig. 1).

Results

In total, two right-handed surgeons completed 20 vessel ligations. The mean TM to perform the loop vessel technique was 557 ± 13 vs 794 ± 9 for the conventional technique ($P < 0.0001$). The mean TP for the loop vessel technique was 14,042 ± 253 m vs 25,906 ± 333 m for the traditional technique ($P < 0.0001$). The mean TT for the loop vessel technique was 50 ± 3 s vs 78 ± 3 s for the traditional technique ($P < 0.0001$). The OSP for the loop vessel technique was 246 ± 6 vs 417 ± 5 for the conventional technique ($P < 0.0001$) (Fig. 3).

Discussion

Suture vessel ligation techniques are essential in surgical practice. Currently, several interchangeable methods have been adopted to increase efficiency and minimise failure of tube ligation, especially in vascular surgery. Examples include energy-assisted ligation, clips and various knot techniques,[1] including pre-formed knots[2,3] and, within general

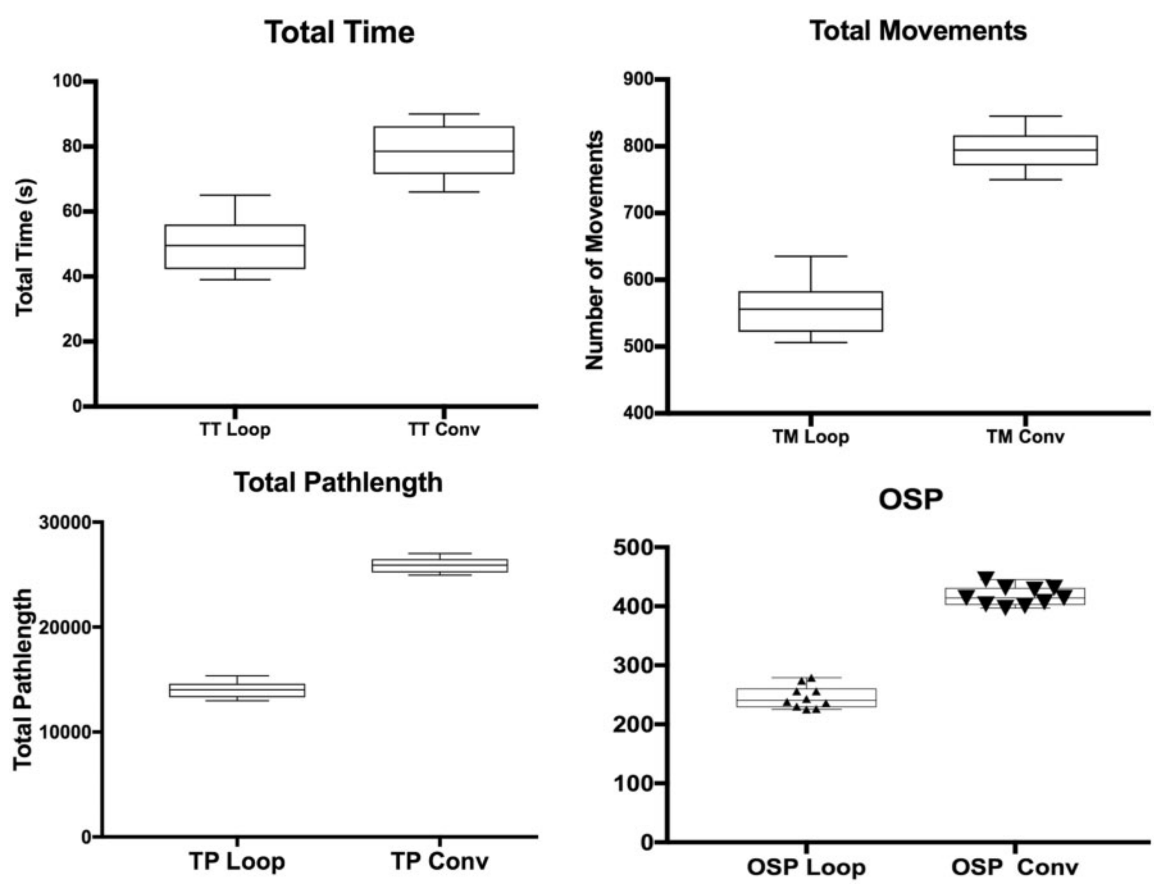

Figure 3. Box plots showing mean ± standard error of mean. All comparisons reached statistical significance at $P < 0.001$. (A) Total movements; (B) total path length (mm); (C) total time; (D) overall surgical performance.

surgery, those applied using purposely designed instruments.[4] However, traditional clamp-suture ligation is still required in a surgeon's armamentarium. From our experience in a microvascular simulation setting, we have found the above loop vessel ligation technique a simple and helpful method to improve efficiency with instrument ties and have transposed this into the clinical setting when raising flaps for soft tissue reconstruction. Although the loop vessel ligation technique described in this article is not novel, it has not previously been studied objectively in terms of surgical efficiency.

We demonstrated objectively that the loop vessel technique significantly improved economy of movement and total time taken to complete the task. Although differences in total time to complete a vessel ligation are small for a single vessel ligation, if multiple vessel ligations are being undertaken within a procedure, the time saved will be cumulative. Within a clinical microsurgical context, even small improvements in time and economy of movement can have significant benefit on overall performance over the course of a long procedure. Therefore, with approximately 30 s saved per ligation, if 20 are performed within a microsurgical vessel preparation, this would result in almost 10 min of microsurgery time saved. In a major general surgical colectomy, it is feasible that 50 vessels may be tied, giving an average time saving of 25 min. However, to look purely at time saved is misleading. To try and demonstrate this, we have combined our results to give a surgical performance score, and this too demonstrated loop vessel ligation to be a significantly better method. In addition, the loop technique does not require an assistant, further increasing the versatility of its use and possible time savings.

This study is not without limitations, such as small sample size and a small number of repetitions. Furthermore, there is a risk of performance bias. To reduce this, participants were blinded to the hand motion analyser results and were not aware of the type of data being collected for the study, therefore preventing adjustments in favour of a specific technique. Furthermore, participants acted as their own control eliminating inter-surgeon variability. Both surgeons were familiar with both techniques, although more commonly used the traditional technique in daily practice. This is reflected in the hand motion millimeter path length measures where we observed a small learning curve in the loop vessel technique, which is to be expected if the surgeons are less familiar with this technique. Taken together, we feel this study demonstrates the benefit of the loop ligation technique compared with the conventional two-suture technique, even by those less familiar with the technique. We hope this article will promote its use amongst trainees and trainers, across surgical sub-specialties, within all settings to increase efficiency of performing vessel ligation.

Conflict of interest

None declared.

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