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TECHNICAL NOTE

Locked Temporary Vascular Shunt for Wartime Vascular Injuries

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Introduction: To reduce the ischaemia time of injured limbs in wartime, temporary vascular shunts (TVS) are commonly used. However, TVS are stabilized at the ends of the injured vessels using manual suture ties, the risk of dislodgement is high, and tightening manual suture ties is too time consuming.

Technical summary: Locked temporary vascular shunts (LTVS) were designed, and each was composed of a silicone tube with a threaded outer surface and smooth inner surface in addition to two nylon buckle switches. The buckle switches were used to stabilize the silicone tube of the LTVS with respect to the vessel walls. This job was performed with two manual suture ties with the current TVS. The mean bursting pressure value of the veins shunted with the LTVS was 114.3% higher than that of the veins shunted with the TVS (0.045 $\pm$ 0.008 MPa vs. 0.021 $\pm$ 0.012 MPa; $p = .00$). Although the mean shunting time of the LTVS was reduced by 60.4% compared with that of the TVS (138.89 $\pm$ 18.22 seconds vs. 350.48 $\pm$ 52.20 seconds; $p = .00$), there was no significant difference in the patency times between the two types of devices (8.20 $\pm$ 9.01 hour vs. 8.40 $\pm$ 8.85 hour; $p = .98$).

Conclusion: The LTVS, which was designed to treat wartime vascular injuries, might be safer and more efficient than the current TVS.

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INTRODUCTION

The conflicts in Afghanistan and Iraq have witnessed an increase in the incidence of vascular injury compared with previous combat reports.[1–6] To reduce the ischaemia time of injured limbs, temporary vascular shunts (TVS) are commonly used.[7] At the Echelon II facility — Forward Resuscitative Surgical Suite in Iraq, upper extremity vascular injuries not amenable to primary repair were routinely shunted by TVS. Once stabilized, with perfusion restored, patients were medically evacuated (MEDEVACed) for definitive treatment and repair at an Echelon III facility.[8] However, because TVS are stabilized at the ends of the injured vessels using manual suture ties, the risk of dislodgement is high,[9] and tightening manual suture ties is too time consuming for military surgeons at Echelon II facilities, particularly when there are large numbers of casualties waiting for rescue.

To eliminate these two problems an improved TVS, the locked TVS (LTVS) was designed. The LTVS has a threaded outer surface and two nylon buckle switches. The objective was to preliminarily evaluate the safety and efficiency of the LTVS.

Supplementary video related to this article can be found at http://dx.doi.org/10.1016/j.ejvssr.2016.07.003.

The following are the supplementary data related to this article:Video S1In the locked temporary vascular shunt insertion procedure, the shunt was stabilized with two buckle switches.

Video S2In the temporary vascular shunt insertion procedure, the shunt was stabilized with four manual suture ties.

SURGICAL TECHNIQUE

Each LTVS (Lituo, Beijing, China) was composed of a silicone tube with a threaded outer surface and a smooth inner surface, in addition to two nylon buckle switches. The length, inner diameter, and external diameter of the silicone tube were 50.0, 3.0, and 6.0 mm, respectively. The threaded internal surface of each buckle switch matched that of the silicone tube (Fig. 1). The length of each buckle switch was

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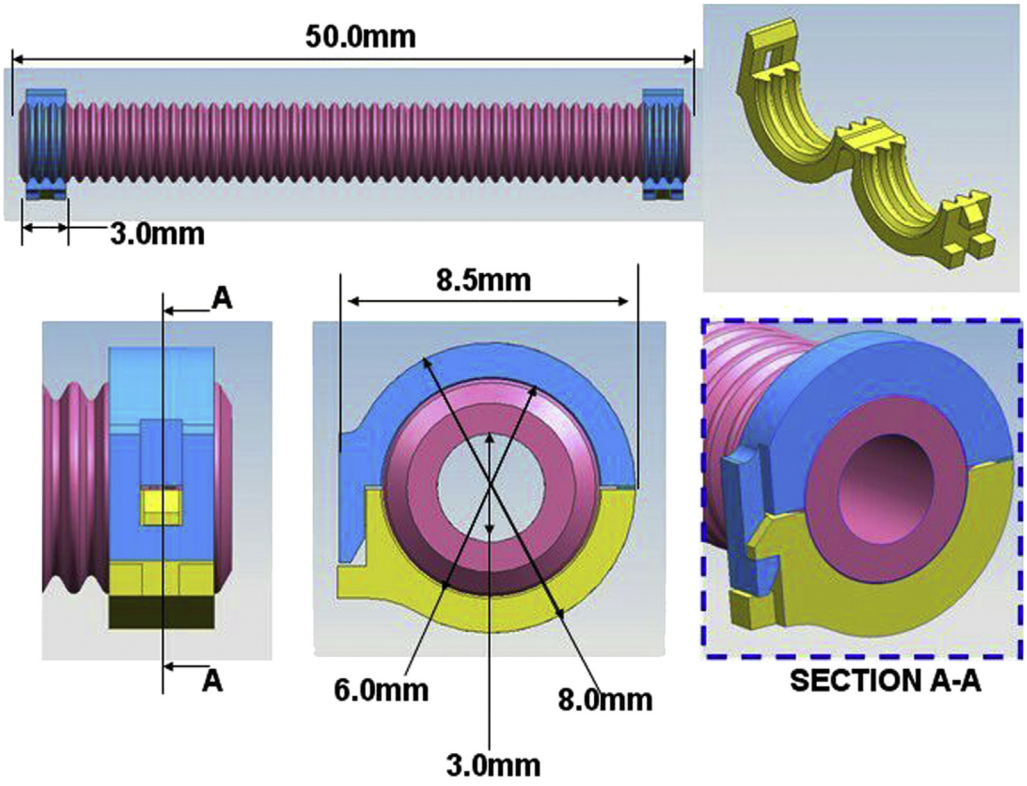

Figure 1. Schematic diagram of the locked temporary vascular shunt.

3.0 mm. Before evaluation, each LTVS was sterilized with 25 kGy gamma irradiation.

Ex vivo *evaluation*

At room temperature, a BD Connecta 394605 three way plastic tube (Becton Dickinson, Helsingborg, Sweden) was connected to a 50 mL syringe (Jierui, Weihai, China) that was fixed to a Graseby 3100 syringe pump (SIMS Graseby, Watford, UK). The other two ends of the three way tube were simultaneously connected to a Junchen piezometer (Huaxia, Zibo, China; range 0—0.1 MPa, accuracy 0.01 MPa) and a sample. A total of 20 samples (10 freshly frozen human brachial veins shunted with 10 LTVS and 10 freshly frozen human brachial veins shunted with 10 TVS) were prepared in parallel and randomly allocated to the two groups for BP measurement. The dimensions of each TVS were 5 mm in outer diameter, 1 mm in thickness, and 50 mm in length. The dimensions of each LTVS were 6 mm in outer diameter, 1.5 mm in thickness, and 50 mm in length. Each LTVS or TVS was stabilized to the proximal end of each vein (approximately 10—15 mm in length with the distal end of each firmly sealed). The freshly frozen human brachial veins were provided by the Bone Tissue Bank of the Chinese PLA General Hospital and were stored in Hank's solution (Sigma-Aldrich, Germany) with 15% dimethyl sulfoxide (Sigma-Aldrich, Munich, Germany) at −80°C before being rapidly resuscitated at 37°C. At each end, the silicone tube of the LTVS or TVS was stabilized using a buckle switch or two manual suture ties. Next, 40 mL saline (0.9% sodium chloride solution) was pumped in at the rate of 199.0 mL/hour. As the saline was continuously pumped, the inner pressure within each sample was simultaneously measured by the piezometer. Bursting represents the time at which disturbance of balance between inner pressure and vessel—shunt friction occurs, regardless of solution leakage or dislodgement. Bursting pressure (BP) means the highest value of inner pressure measured at the time of bursting, and therefore equals the maximum value of friction at the connection site between vessel and shunt. Brachial veins were harvested from donors registered at Bone Tissue Bank of the Chinese PLA General Hospital. All donors signed organ donation consent, and the ethics committee of the Chinese PLA General Hospital (Beijing, China) approved this study. The mean BP of the veins shunted with the LTVS was 114.3% higher than that of the veins shunted with the TVS (one-sample *t* tests [SPSS 13.0; IBM, Armonk, NY, USA], $p = .00$; Table 1).

In vivo *evaluation*

The *in vivo* evaluation was conducted under a protocol approved by the Institutional Animal Care and Use Committee of the Chinese PLA General Hospital. Five healthy adult hybridized dogs weighing 12.10 ± 4.79 kg provided by the Keyu Aquaculture Center (Beijing, China) under certificate No. SCXK 2007-0003 were used in the study, and each was used as its own control. The bilateral femoral arteries were randomly selected for shunting with an LTVS or a TVS (the inner diameters of the two shunts in each dog were the same). Before surgery, the dogs received intramuscular morphine and atropine as pre-anaesthesia and intravenous