J Vasc Access 2013; 14 (2): 116-119
DOI: 10.5301/jva.5000107

ORIGINAL ARTICLE
OPEN ACCESS

# A sterile elastic exsanguination tourniquet is effective in preventing blood loss during hemodialysis access surgery

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**ABSTRACT**

***Purpose:*** **We report the first use of a sterile elastic exsanguination tourniquet (SET) in performing hemodialysis vascular access procedures in 27 patients. The main advantages of this tourniquet are the reduction of blood loss and need for possible transfusions. Additional benefits are the near-perfect exsanguination and excellent exposure of the operative field.**

***Methods:*** **This SET is a sterile elastic stockinet device that rolls up the arm starting from the hand by pulling on two handles. The elastic silicone ring provides sufficient pressure (220 ± 30 mmHg) to block arterial flow into the limb. The stockinet can be cut to provide access to the incision area while providing an additional sterile cover over the rest of the limb.**

***Results:*** **No transfusions were required in any patients. Minor adverse effects occurred in four patients, including a twisted vessel, a bleeding vascular branch, a tear in atrophic arm skin, and pain, all of which had resolved on subsequent follow-up. Operational recommendations to avoid these adverse effects are outlined.**

***Conclusions:*** **We conclude that this sterile elastic exsanguination tourniquet is effective and safe in preventing bleeding during upper extremity hemodialysis vascular access procedures.**

**Key words: Arteriovenous fistula, Dialysis access, Hemodialysis, Tourniquet use, Upper extremity**

Accepted: August 11, 2012

## INTRODUCTION

Pneumatic tourniquets have been reported to be useful during dialysis access surgery of the forearm (1). These tourniquets may reduce the duration of the surgery and the arterial spasm provoked by the dissection. Moreover, when microsurgical techniques and preventive hemostasis are used, it is possible to create fistulas even in very small children. However, when an arteriovenous fistula is created or revised in the upper arm, there is often not enough space for the pneumatic tourniquet between the axilla and the surgical incision. As such, these operations are performed without a tourniquet, leading to substantial blood loss and sometimes a transfusion. It is desirable to minimize the use of transfusion in all patients with end-stage renal failure because of the risks of viral transmission. In renal transplant candidates, it is particularly important to avoid transfusion because of risk associated with sensitization to human lymphocyte (HLA) antigens, known as the panel-reactive antibody (PRA), which may induce rejection (2,3).

Recently, we started using an ultra-narrow, non-pneumatic exsanguination tourniquet (HemaClear®, OHK Medical Devices, Haifa, Israel). This surgical exsanguination tourniquet (SET) is a sterile elastic stockinet device that rolls up the arm starting from the hand by pulling on two handles. The elastic silicone ring provides sufficient pressure (220 ± 30 mmHg) to block arterial flow into the limb. The stockinet can be cut to provide access to the incision area while providing an additional sterile cover over the rest of the limb. This tourniquet is being used extensively in orthopedic surgery for both upper and lower extremity procedures. The available sizes accommodate limb circumferences ranging from 14 - 90 cm. This report describes our experience with this device with special attention to several adverse effects we have encountered and specific recommendations for its safe use in dialysis access surgery. We believe this to be the first report of using this tourniquet in dialysis access surgery.

## MATERIALS AND METHODS

Institutional Review Board/Ethics Committee approval was obtained for this study. Between August 1, 2011 to January 5, 2012, we utilized a SET in 27 dialysis access procedures – 17 in the forearm and 10 in the upper arm. The SET can be deployed quickly on the patient's arm and performs three functions: blood removal (exsanguination), arterial flow occlusion and automatic application of a sterile stockinet (4). Table I shows the types of procedures performed. After appropriate anesthesia is induced,

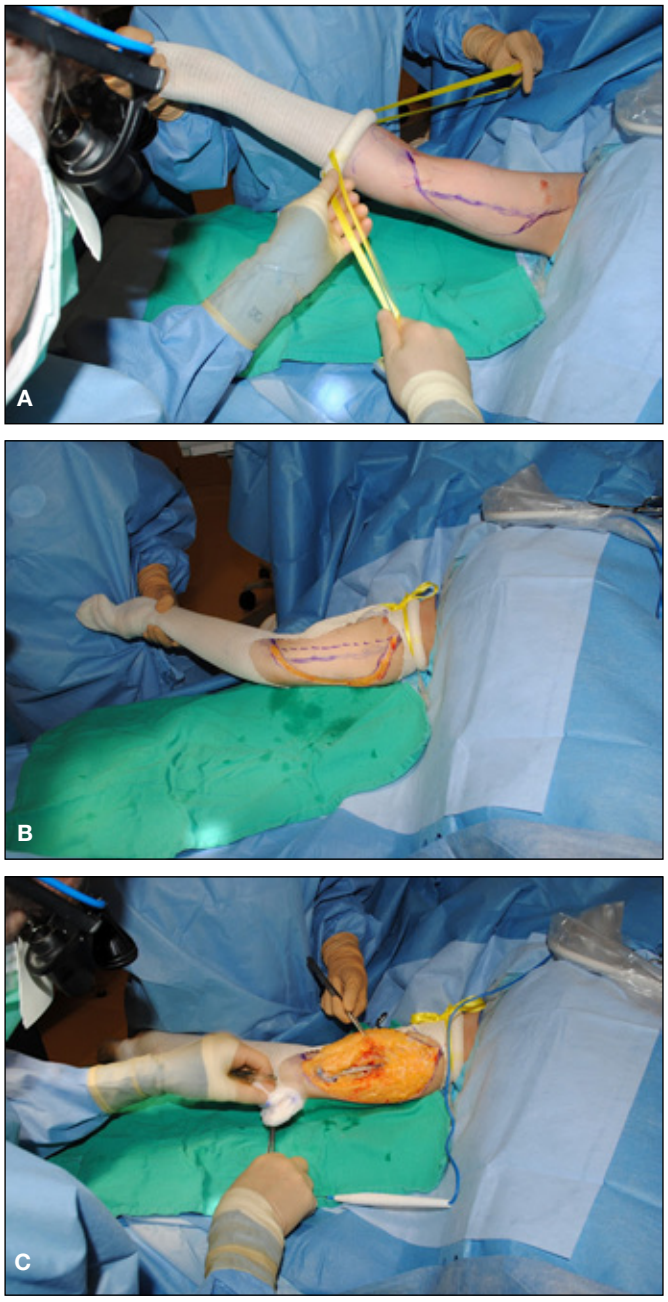


**Fig. 1 -** *A) The SET is applied to the patient's arm by pulling the straps. B) The SET is in place and the first incision has been made. C) The vessels are dissected bloodlessly.*

the SET is applied to the arm by pulling the straps and rolling the ring up the arm (Fig. 1a). With the SET in position with the ring just distal to the deltoid, the material is cut to provide wide surgical site exposure in the upper arm with no bleeding from the incision (Fig. 1b). The SET allows excellent visibility of the anatomic structures because of the near-perfect exsanguination with no residual blood in the arm (Fig. 1c). After the procedure is completed but before wound closure is commenced, the SET is removed by cutting the ring with a scalpel, with care taken to avoid inadvertent nicking of the skin.

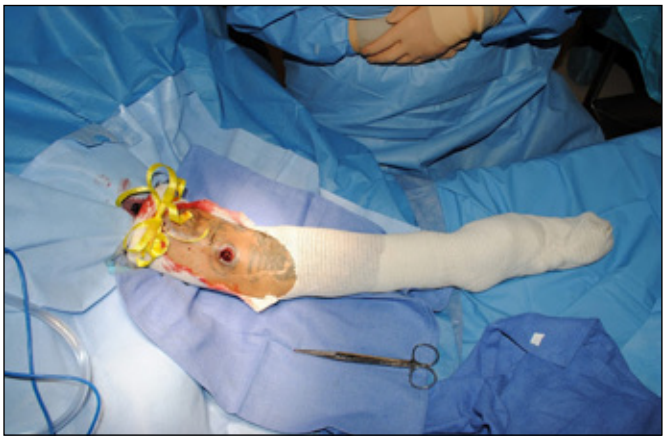

**Fig. 2 -** *The SET is applied over an ulceration requiring surgical removal.*

The SET is also effective in providing a bloodless operative field for dissection of an ulceration at the site of a dialysis vascular access fistula. The sterile SET is rolled over the lesion and the fabric of the stockinet cut to expose the surgical site (Fig. 2). The lesion can be dissected widely with essentially no blood loss. The wound is closed after the SET is removed.

## RESULTS

The follow-up period ranged from 1 - 8 months (mean, 3.5 months). In all 27 cases, hemostasis and surgical exposure were excellent. The SET enables exposure, dissection and manipulation of upper arm blood vessels under tourniquet control. In all but one case, blood loss was < 20 mL. There were four adverse events that resolved (Tab. II).

**TABLE I -** TYPES OF PROCEDURES PERFORMED

| Forearm | Cases (n) |
|---|---|
| Radiocephalic fistula | 4 |
| Brachiocephalic fistula (direct anastomosis) | 8 |
| Brachiobasilic stage 1 (direct anastomosis of brachial artery to basilic vein) | 4 |
| Removal of infected arteriovenous graft of the forearm | 1 |
| Upper arm | |
| Brachiocephalic fistula (extensive transposition) | 2 |
| Brachiobasilic stage 2 (extensive transposition of the basilic vein) | 6 |
| Removal of infected arteriovenous graft of the upper arm | 2 |

**TABLE II -** SUMMARY OF FOUR ADVERSE EVENTS

| Adverse Event | Outcome/Treatment |
|---|---|
| Skin Tear | Patient with edematous, atrophic skin had skin avulsion that healed without further surgery. |
| Post-operative hemorrhage | Wound closed before tourniquet was removed. Post-operative hemorrhage from unsecured brachial artery branch treated by reoperation. |
| Pain | Resolved with removal of the tourniquet. |
| Unrecognized twisted vein | Vein was harvested and tunneled under tourniquet control. Twisted vein was recognized only after tourniquet was removed. |

## DISCUSSION

An arteriovenous fistula (AVF) is the preferred access for performing hemodialysis. The AVF is a very high-flow reconstruction of the vascular system. Normal blood flow to the arm is 100 - 150 mL/min but the typical blood flow in an AVF is 600 mL/min and can be ≥ 2000 mL/min. Creation or revision of an AVF is sometimes associated with substantial blood loss. Despite the availability of erythropoiesis-stimulating agents, it is still not uncommon for patients with renal disease, even those awaiting transplant, to need and receive blood transfusion after AVF procedures. Transfusion is a leading cause of sensitization to HLA antigens (PRA) and the degree of sensitization is increased with more units transfused (3). It has also been shown that patients with high PRA levels wait longer for a transplant than patients with low PRA levels (3). Therefore, the ability to perform the required vascular access procedure with minimal blood loss is highly desirable.

The SET exerts pressure comparable to pneumatic tourniquets – approximately 200- 250 mm Hg for the upper and 300 - 350 mm Hg for the lower extremity. There are four sizes that can be used for limb circumference ranging from 14 - 90 cm limb circumference. The size for each patient is determined by measuring limb circumference at the required occlusion site and by the systolic blood pressure, according to a table provided with the device (5). In contrast to the traditional pneumatic cuff tourniquet, the SET's silicone ring applies a more narrow region of pressure. While there may be concern about possible tissue damage because of higher pressure applied to a narrow area, there have been no reports of tissue damage from use of this SET, in over 300 000 units sold (6). Furthermore, a recent study found that nerve injury was 12 times more prevalent with a traditional wide cuff pneumatic tourniquet than with the SET (7).

Another study compared the tolerance and recovery time of a pneumatic cuff tourniquet and a silicone ring tourniquet applied to the upper arm and thigh using healthy volunteer subjects (8). The subjects rated pain associated with the use of both tourniquet types using a visual analog scale; arterial blood pressure, pulse rate and oxygen saturation were also monitored. There were no statistically significant differences in tolerance time and recovery between the two tourniquets (8).

The traditional pneumatic tourniquet is of limited effectiveness in upper arm AVF surgery. The SET described in this report is much narrower than the pneumatic tourniquet and has enabled AVF and grafts to be performed in the upper arm. One excellent use of the roll-on SET is in the creation of the transposed brachiobasilic fistula. The basilic vein of the upper arm can be harvested readily through either long incisions or multiple small incisions with long skin bridges. When harvesting the basilic vein through long incisions, the SET limits blood loss. When harvesting the basilic vein through small incisions with long skin bridges, absolute hemostasis is essential for adequate exposure and visualization. Similarly, the SET has enabled extensive harvesting transposition of the cephalic vein of the upper arm to be performed almost bloodlessly. Additionally, one of the bloodiest procedures in dialysis access surgery is removal of the infected upper arm arteriovenous graft. With the SET rolled up to the junction of the axilla and the upper arm, the infected upper arm graft can be removed with very little blood loss.

There are some precautions to consider when using the SET inherent to its major effectiveness in interrupting blood flow. After harvesting the basilic or cephalic vein under tourniquet control, it is essential to remove the SET prior to tunneling the vein in order to be able to flush the vein with heparinized saline and verify that it is not twisted. If the tourniquet is left in place during the tunneling process, there will be some uncertainty as to whether the vein is twisted. A twisted vein will result in technical failure of the procedure. Thus, before tunneling, we recommend that the SET always be removed and that the vein be double-checked for twists.

Another pitfall that must be avoided is related to the high blood flow in the arm when an AVF is present. The SET must be removed and hemostasis verified prior to wound closure. If the tourniquet is left in place until after the wound is closed, tiny unligated branches of the fistula may cause very serious bleeding. If no fistula was present, the small venules would ordinarily create no problems for surgical hemostasis but in the renal patient with an AVF, the abnormally high blood flow and venous pressure will cause wound hematomas and complications unless extra attention is paid to final hemostasis. We recommend never closing the AVF surgical incision until after the SET has been removed.

Caution should be exercised in patients with very poor skin integrity. The process of rolling the tourniquet up the

arm applies some shear stress to the skin. Some patients with chronic renal disease have atrophic skin and edema that heightens their susceptibility to skin tears (1). In addition, the SET is sterilized with ethylene oxide, which could be an allergic concern for some hemodialysis patients (6).

Care must be taken to provide adequate analgesia or anesthesia, as the hemostatic force of the SET is concentrated into a narrower zone than a pneumatic tourniquet. If regional anesthesia is used, consider that the application zone of the SET at the junction of the axilla and upper arm is innervated by the intercostobrachial nerve, which can be missed during some brachial plexus nerve blocks. If local anesthesia is used, additional sedation may be needed (2).

## CONCLUSIONS

We report what we believe to be the first successful use of a SET with a narrow footprint in 27 hemodialysis patients. The main advantage is the prevention of blood loss in upper arm procedures that would have otherwise been performed without a tourniquet and could have resulted in substantial bleeding and possible need for blood transfusion. No transfusion was required in this group. Additional benefits are the near-perfect exsanguination, excellent exposure and visibility and the avoidance of direct placement of vascular clamps on the blood vessels with the ensuing risk of spasm and intima shearing. We encountered adverse effects in four of the cases, including a twisted vessel, a bleeding vascular branch, a tear in atrophic arm skin and pain. Subsequent follow-up of these patients has not been associated with any adverse effects that could be attributed to the use of the SET. We conclude that the SET is effective and safe in preventing bleeding in upper extremity hemodialysis vascular procedures and, in particular, in reducing the need for blood transfusion.

**Financial support:** None.

**Conflicts of interest:** The authors were not remunerated nor do they have any financial association with the manufacturer of the HemaClear® tourniquet (www.hemaclear.com).

**Meeting presentations:** Poster presented (2nd place award) at the annual meeting of the American Society of Diagnostic and Interventional Nephrologists, Feb. 25, 2011, New Orleans, LA, USA.

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