

Pulmonary Embolism After Application of a Sterile Elastic Exsanguination Tourniquet

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abstract

Sterile elastic exsanguination tourniquets (HemaClear; OHK Medical Devices, Haifa, Israel) are relatively new on the market but are widely used because of the ease and speed of their application. The sterile elastic exsanguination tourniquet consists of a silicon ring wrapped in a stockinet sleeve with pull straps. The physician places the ring on the patient's fingers or toes and then pulls the straps proximally. The silicon ring rolls up the limb, and the stockinet sleeve unrolls onto the limb. During proximal rolling, the device displaces blood out of the limb (exsanguination). When the elastic ring reaches the preferred occlusion location, the pulling motion is stopped. The ring exerts suprasystolic pressure on the limb, thereby blocking arterial blood flow into the limb and thus acts as a tourniquet. HemaClear tourniquets are thin and sterile and therefore provide a large operative field. The authors report 2 cases of pulmonary embolism after HemaClear tourniquet application in patients with traumatic injuries (fractures of the patella and tibial plateau). Exsanguination applies mechanical stress that might dislodge a preexisting deep venous thrombosis, leading to the serious complication of pulmonary embolism. The authors want to increase awareness of this possible fatal complication during procedures performed on the lower limbs, when the HemaClear tourniquet is used for exsanguination of the affected limb. Careful consideration should be given to the use of HemaClear tourniquets in high-risk patients and those with traumatic injuries, especially when there has been a delay in surgery. [*Orthopedics*. 2015; 38(12):e1160-e1163.]

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The modern tourniquet was introduced by Friedrich von Esmarch in 1873 using an elastic (“Esmarch”) bandage that was improved in 1908 by Dr. Harvey Cushing with the introduction of the pneumatic tourniquet.

To achieve a bloodless surgical field and reduce intraoperative blood loss, the orthopedic surgeon can exsanguinate the limb (eg, elevate the limb before surgery), exsanguinate the limb and occlude blood flow to the limb with an Esmarch bandage, or only occlude blood flow to the limb with a pneumatic occlusive tourniquet.

Recently, the authors started to use a new sterile elastic exsanguination tourniquet (HemaClear; OHK Medical Devices, Haifa, Israel) for bloodless limb surgeries, traumatic injuries, and elective procedures. This device is meant to replace the traditional pneumatic tourniquet and has 3 functions: (1) it removes blood from the operated extremity (exsanguination); (2) it occludes arterial flow; and (3) it serves as a sterile stockinet.¹⁻⁴

The sterile elastic exsanguination tourniquet is a silicone ring wrapped in a stockinet sleeve with 2 pull straps. The physician places the ring on the patient’s fingers or toes and then pulls the straps proximally. The silicone ring rolls up the limb, and the stockinet sleeve unrolls onto the limb (Figures 1-2). During proximal rolling, the device displaces blood out of the limb. When the elastic ring reaches the preferred occlusion location, the pulling motion is stopped and the ring blocks arterial blood flow distally (Figure 3). The ring exerts suprasystolic pressure on the limb, blocking arterial blood flow into the limb, and thus acts as a tourniquet. During rolling of the ring, a stockinet sleeve unrolls onto the limb and covers it entirely up to the level of occlusion, thereby draping a sterile cover over the surgical field (Figures 2-3).

At the end of the procedure, the silicone ring is cut with a blade. The sterile stockinet is cut away with scissors, and the blood supply to the limb resumes.



Figure 1: Photograph showing the physician placing the ring on the toes.

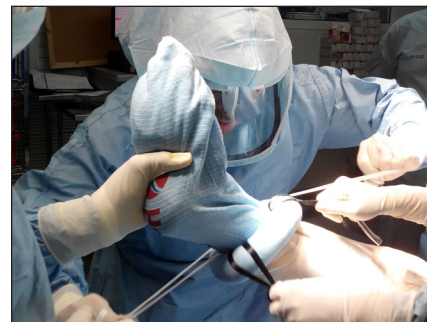


Figure 2: Photograph showing the physician pulling the silicone ring proximally.

Many reports have been published on pulmonary embolism that occurs when an Esmarch bandage is applied to traumatized lower limbs.⁵

This serious and often fatal complication has not been reported with the use of the sterile elastic exsanguination tourniquet.

This article reports 2 such cases. To the best of the authors’ knowledge, this is the first report of the association between pulmonary embolism and the use of this tourniquet.

CASE REPORTS

Patient 1

A healthy 65-year-old woman was admitted to the authors’ hospital after she had a patellar fracture of the left knee as a result of a motor vehicle accident. She had no other concomitant musculoskeletal injuries.

On admission, a thorough medical examination showed no obvious abnormalities. The patient’s blood profile and coagulation status were normal. She was not overweight and did not smoke.

Initial management included immobilization of the fractured limb in a long cylindrical (tutor) cast. The patient was encouraged to be mobile in the ward; therefore, no anticoagulant therapy was administered.

The patient underwent fixation of the fracture 9 days after the injury. The anesthesiology team induced general anesthesia with intravenous midazolam and

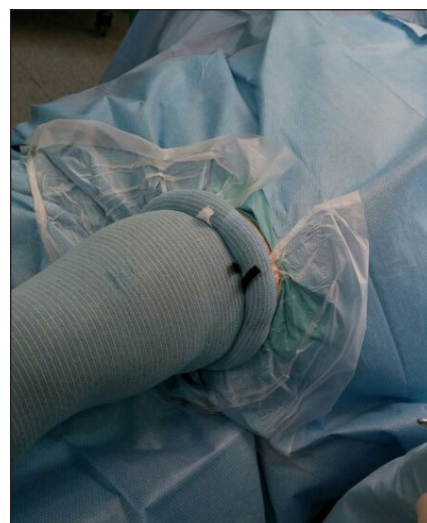


Figure 3: Photograph showing the stockinet sleeve unrolled on the limb and covering it entirely up to the level of the occlusion level, with a sterile drape covering the surgical field.

fentanyl, and tracheal intubation was facilitated by succinylcholine. A HemaClear tourniquet was then rolled onto the injured limb from the toes to the mid thigh. Immediately, the patient became cyanotic and tachycardic, blood pressure dropped rapidly from 140/90 mm Hg to unmeasurable, heart rate increased from 40 beats/min to 120 beats/min, and end-tidal carbon dioxide partial pressure decreased to 17 mm Hg within 1 minute. Blood gas results showed serious respiratory acidosis. The tourniquet was immediately released, and the limb was immobilized in a cast. Computed tomography angiography showed bilateral pulmonary emboli. Intravenous heparin was administered, and

the patient was successfully extubated the next day. An inferior vena cava filter was implanted, and fixation of the patellar fracture was successfully performed a day later. The patient was discharged 7 days after surgery in good general condition.

Patient 2

A 53-year-old man with a history of untreated high blood pressure and chronic renal failure presented to the emergency department with an isolated right tibial plateau (Schatzker VI) fracture after a motorcycle accident.

On the day of admission, the fracture was stabilized with an external fixator. Definitive stabilization surgery was scheduled, and the patient was discharged from the department with no preventive anticoagulation treatment.

Twenty-six days after the accident, the patient was admitted for internal fixation of the fracture. Before surgery, he was in good general health and had normal vital signs, with oxygen saturation of 99%. During surgery, the HemaClear tourniquet was applied, and 1 minute later, oxygen saturation dropped suddenly to 90%.

The patient became tachycardic but was normotensive. Arterial blood gas values showed severe acidosis. A chest radiograph obtained in the operating room showed normal placement of the endotracheal tube. No atelectasis or edema was evident. The anesthesiologist could keep the oxygen saturation above 95% with 100% oxygen. After consultation with the anesthesiology team, a decision was made to proceed with surgery. The procedure was performed as quickly as possible and concluded after 90 minutes. Immediately after surgery, the patient underwent computed tomography arteriography, but shortly afterward, he had extreme bradycardia of 40 beats/min and the blood pressure dropped to 80/50 mm Hg. Resuscitation was immediately begun, but the patient's condition soon deteriorated to a state of pulseless electrical activity. Heart echocardiography showed a dilated

right ventricle, with global dyskinesia and severe left ventricle dysfunction. Doppler ultrasound of the lower limb showed deep venous thrombosis (DVT) in the right femoral vein. Despite continuous resuscitation attempts, including full heparinization and thrombolysis therapy with tissue plasminogen activator, resuscitation efforts were unsuccessful. The patient could maintain normal blood pressure values only with the administration of inotropic drugs.

Two days later, the patient was declared brain dead and his family decided to discontinue mechanical ventilation. Postmortem examination showed that the cause of death was multiple pulmonary emboli in the right heart, completely blocking both of the pulmonary arteries.

DISCUSSION

Sterile elastic exsanguination tourniquets are relatively new on the market but are widely used because of the ease and higher speed of application compared with pneumatic tourniquets. Another advantage of these tourniquets is the fact that they are thinner than most pneumatic tourniquets and, in contrast to pneumatic tourniquets, they are sterile and therefore can provide a larger sterile operative field.

An important advantage of the sterile tourniquet is that it squeezes the blood out of the extremity during the process of proximal rolling. When the tourniquet reaches a more proximal position on the limb that is wide enough to hold it, the tourniquet blocks arterial flow into the extremity.⁶ The authors assume that in these patients the proximal rolling and squeezing created mechanical stress that suddenly accelerated venous flow and was the main cause of the release of a thrombus from its origin in the deep venous system of the lower extremity to the main circulatory system and from there to the pulmonary arteries.

Trauma, immobility, and surgery predispose patients to DVT. Although a

thrombus can embolize spontaneously, the mechanical stress caused by an Esmarch bandage or a tourniquet is believed to cause a sudden increase in the velocity of venous flow and dislodge the preexisting thrombus, causing a pulmonary embolism. Some reports mentioned pulmonary emboli after the application of Esmarch bandages, and it is believed that a preexisting DVT is moved to the lungs by the centripetal direction of the blood flow. A number of cases in the literature have reported the association of pulmonary embolism with pneumatic tourniquets. In these cases, the pulmonary embolism episodes occurred immediately after inflation or deflation of the tourniquet. Pulmonary embolism occurring after inflation is explained by the increase in compartment pressure in the limb when the tourniquet is inflated, and this may be sufficient to dislodge the thrombus. When pulmonary embolism occurs after tourniquet deflation, the general assumption is that a period of venous stasis results in local thrombosis, with subsequent embolization once the tourniquet is deflated.⁷

Acute massive pulmonary embolism is a very serious condition; 50% of patients are expected to die within 15 minutes, and only 33% survive longer than 2 hours.^{8,9}

When all reported cases of pulmonary embolism after Esmarch bandage application were compared, the most important parameter was a delay in surgical treatment of 5 days or more.⁵

Pulmonary embolism may have various manifestations under anesthesia, such as sudden onset of breathlessness, loss of consciousness, hypotension, and a decrease in end-tidal carbon dioxide. The usual electrocardiogram findings are ST-T changes seen on the right-sided leads, right bundle branch block, and electromechanical dissociation. Transesophageal echocardiography has high sensitivity and specificity in detecting pulmonary embolism and right ventricular dilation. Transthoracic echocardiography can show right ventricular hypokinesia and dilation,

but is not sensitive in identifying an embolus. An increase in the plasma level of D-dimer can help to correlate the diagnosis, even though it is not specific for DVT. Normal levels of D-dimer help to rule out DVT.⁷

Patient 1 had no predisposing factors for DVT, and her mobility was not restricted. Therefore, prophylactic anticoagulation treatment was not considered necessary.

Patient 2 was immobilized, but did not meet the criteria for anticoagulation treatment and therefore was not given anticoagulation treatment.¹⁰

Although it is customary to use a tourniquet to provide better visualization of the surgical field and decrease blood loss, there is no absolute indication for the use of a tourniquet when performing the procedures described in this article (patella and tibial plateau repair). Many reports have described safe application and possible adverse effects, but the decision to use a tourniquet is up to the surgeon. At the authors' institution, some surgeons use tourniquets, but others prefer to operate without them.¹¹

Diagnostic tests for DVT are invasive, are not sensitive, and are expensive, mak-

ing routine use difficult. Diagnostic work-up should be considered in patients who are immobilized for more than a few days if use of a tourniquet is planned.⁷

Although the number of cases reported here is too limited to allow definitive conclusions, the authors recommend extreme caution and even suggest avoiding the use of an exsanguination tourniquet in patients undergoing elective surgery who have risk factors for DVT and in patients with traumatic injury of the extremities because these patients are at risk for DVT.⁵

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