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WAR SURGICAL REPAIR OF ARTERIAL INJURIES BY USING ANTERIOR RECTUS SHEATH GRAFT

Izvješće o zbrinjavanju ratnih ozljeda arterija zakrpom od prednjeg lista ovojnice ravnog trbušnog mišića

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Dear Editor,

the intention of this letter is to report how we performed surgery on the spot, under war and battle conditions. The aim is not to teach, propose, make surgical strategy or even doctrine. Just to report how it was done, ON THE SPOT, during the last war in Croatia.

This is a war surgeon's report of experimental and clinical experiences using the anterior rectus sheath graft (the strongest membrane in the human body) as a patch for repair of great arteries injured under war conditions. Such injuries are primarily contaminated and the use of xenografts can be dangerous due to infection. The rectus sheath patch as a potentially growing material was used for repair of congenital heart lesions as atrial septal defect (ASD) primum type. Experimentally, in sheep, the rectus sheath graft was used for repair of femoral arterial artificial lesions. After six months the affected vessels were histologically examined. In both models, animal and human, so far hasn't been observed: early bleeding from rectus sheath patches, infection, aneurysmal dilatation or scar contraction. No manifestation of peripheral emboli was seen as well as no aneurysmal formations, rupture, calcifications or deformations. On the contrary, so far the covering of the lumen by vascular endothelium, laminations of media, formation of serosa layer elements and vascularization of the graft and adventitia like tissue have been observed and reported. During the Croatian War of Independence this kind of surgical repair has been applied on 184 patients with excellent results.

Conclusion

The material is suitable for surgical repair of great vessel injuries, because it is as an autograft usable in infected wounds and available on the spot in satisfactory size in the body of the patient, which is crucial for on the spot application in the field, and it has a growing potential and does not require anticoagulant therapy.

Introduction

The great Croatian war surgeon Prim. Dr. Vatroslav Florschütz wrote a serial of reporting letters from the battle fields in the World War I to illustrate to the following generations of surgeons [1] the

implementation of great surgery on battle spot.

This letter is following his work with the same aim: to inform new coming generations of surgeons about surgery under war conditions and on the spot in the last war in Croatia.

Open war surgical wounds are mostly contaminated. Great arteries are very often damaged in open wounds caused by high velocity missiles or sharp weapons [2, 3] widely used in war conflicts, especially in low intensity wars as the one in Croatia 1990–1996 [4, 5]. Elective surgical repairs like lateral vessel suture and prosthetic xenograft are not appropriate due to extended arterial damage caused by molecular stress and infection of war wounds. Very often xenografts are not available on the spot in field surgery [2, 3]. The use of the patient's vein graft is very often limited by the caliber and area of damaged artery. Delay in operation or transportation very often leads to amputation of the limb, because the golden period for repair of the great arteries is only few hours or even less. At the beginning of the Croatian War of Independence a team of war surgeons from the Mobile Surgical Teams (MST) of the Croatian Special Police Forces (SJP-MUP-RH) [4, 5] began a research concentrating on material which is as a homograft suitable for use for repair in the host's infected wound and as human tissue available on the spot as a part of the victim's body.

Following surgical experiments and results of Anagnostopulos, Coursair and Lam [6–8], the research started with experimental surgery on arteries of sheep. Early and late results encouraged us to continue. After histologic confirmations that the anterior rectus sheath graft is suitable for repair of the great arteries, we started to use such patches as autografts for surgical repair of human arteries under war conditions, on the spot.

Material and methods

The anterior rectus sheath used as a patch for surgical repair of arteries was first tested on animals. After reconfirmation that the anterior rectus sheath patch is a suitable material for surgical repair of arteries, the patch was used as a material for surgical repair of arteries under war conditions.

Animal experiment

Fifty sheep aged four weeks (breed Croatian Pramenka) were operated upon.

Surgical technique: sedation by Sedalin (acepromazin) 0.1 mg/kg and I.V. anesthesia by ketamine 10 mg/kg.

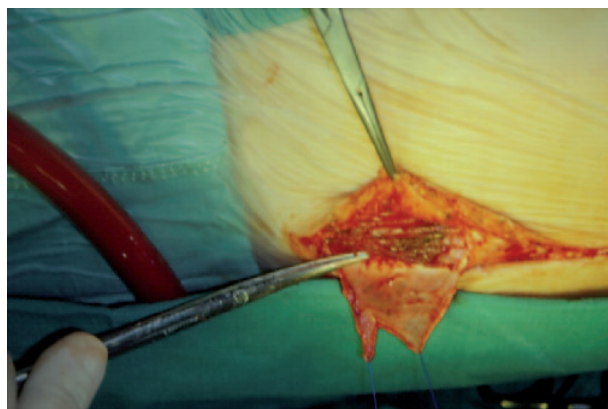
The anterior rectus sheath patch was placed on the longitudinal incision of both femoral arteries. The external surface of the anterior rectus sheath always has to be placed towards the lumen of the vessel. During the first five postoperative days the blood flow was controlled with a Doppler device. After six months the arteries were examined histologically.

War surgical experience

During the Croatian War of Independence in every unit of the Special Police Forces a Mobile Surgical Team was incorporated [4, 5], sometimes more than one depending on strategic situation on the spot, following the Croatian War Surgical Tradition and the strategy of the father of Croatian field surgery Prim. Dr. Vatroslav Florschütz from the World War I [1].

The anterior rectus sheath as a patch for surgical repair of arteries was widely used as a standard procedure by Mobile Surgical Teams. Surgical procedures on various arteries and the number of complications are shown in Table 2. Surgical technique was very simple; after stabilization of the patient and indication for surgical repair of arteries, a patch of the anterior rectus sheath was removed through perirectal incision. The damaged artery was repaired using such a patch or tubular graft. The tubular graft was formatted according to size and length of the damaged artery. First approximation of proximal and distal anastomosis diameter was performed, using single and running stitches. Then the lumen was closed with a longitudinal running stitch. No wrapping of the graft was performed. Surgical techniques by Volmar, Carrel and Zollinger were commonly used. The grafting should always position the external surface of the anterior rectus sheath towards the lumen of the vessel. The patient was monitored in a standard way.

Figure 1. Preparation of the anterior rectus sheath graft.



The patients were not placed on anticoagulant therapy due to lack of proper monitoring, possible reoperations and concomitant lesions of other organs and systems. Monitoring was performed with a portable Doppler machine and clinical observation of the limb and/or wound. After the casualties stabilized, they were transported to hospitals in non-combat areas of the country, mostly by helicopter. No later complications were recorded or reported.

Results

Experimental surgery – animal model

Table 1 shows that there were no surgically related complications among sheep operated upon using the anterior rectus sheath graft as a patch to close the incision of both femoral arteries. After six months the sheep continued their growth together with their arteries, without any signs of circulation related problems.

Histologic examination of the operated part of each artery was performed.

Table 1. Experimental surgery – animal model.

Arteries	Rectus patch	Bleeding	Thrombosis	Infection	Other surgical complications
Common femoral right	50	0	0	0	0
Common femoral left	50	0	0	0	0
Total	100	0	0	0	0

Macroscopic and microscopic histologic findings

Macroscopic

Repaired parts were intact without any signs of thrombosis, calcification or formations of aneurysm. Consequently, there were no signs of degeneration of the operated part of the vessel after the application of the anterior rectus sheath patch.

Microscopic

They showed normal vessel thickness of the vessel wall, without any calcifications.

Three layers of transmural zones:

1. intimal layer shows cellular proliferation with endothelium,
2. media shows fibrous lamellas,
3. external layer shows adventitia like tissue vascularized like normal adventitia of the great vessels.

War surgical results are listed in Table 2.

The patients were operated by surgeons of the Mobile Surgical Teams on the spot or in the nearest hospital by surgeons from the MST.

The mean age of the included patients was 23.58 +/-7. Gender 100% males.

It is visible that the anterior rectus sheath graft was used in 114 (57%) cases of the entire war surgical repair of great arteries, mostly on aorta and iliac arteries, and femoral arteries to the level of about 100%.

Lower arteries were repaired by other surgical techniques, so the use of rectus patch or tubular graft was mostly on the great arteries.

Number of early reoperations: on 29 patients (14%) due to thrombosis and on 17 patients (9%) due to early postoperative bleeding.

No later complications were recorded or reported.

Table 2. Early postoperative complications. War surgical repair.

Artery	Number	Patch	Tubular graft	Intervention / thrombosis	Intervention / bleeding
Aorta abdominal	12	12	0	0	3
Iliac common	14	14	0	0	2
Iliac external	8	8	0	0	1
Femoral common	46	46	0	5	5
Femoral superficial	28	12	16	7	2
Popliteal	52	12	27	4	1
Axillar	21	7	14	5	2
Brachial	16	3	13	8	1
Total	197	114	70	29	17

Discussion

Material of choice for surgical arterial repair under war conditions

War injuries of the great arteries and veins are a common cause of war mortality and morbidity [3, 4]. During war surgical history various techniques have been applied: compression, cauterization and mostly ligation and amputation [2, 3, 8]. Ischemia leads to amputation and massive bleeding, and to shock and sepsis. Late in war surgical history appeared surgical reconstruction of blood vessels on the spot – battlefield hospitals [2, 3, 8]. Venous allografts and homografts are suitable in low percent of casualties. In elective non-war vascular surgery prosthetic grafts are commonly

used and followed by low complication rate. Indication for the use of synthetic grafts in war vascular surgery is very narrow, only for blunt injuries. In the Vietnam War, the surgical team of colonel Rich mostly used the vein [3]. In case of that vein being unsuitable, amputation was performed [3].

Frequent problems associated with the use of synthetic grafts are: infection, thrombosis, sepsis and amputation.

Venous homograft

This is a common method with some limitations: not enough material for the repair of big vessels, especially aortic, iliac and femoral arteries. The veins of upper extremities have a small caliber. Neck veins are not suitable for surgical repair of blood vessels. Serious circulatory problems and even thrombosis were reported after extirpation of lower extremity veins. This can compromise recovery of polytrauma patients. Surgical cleaning of the other extremity and preparation of the vein is very often a waste of time [3].

Results of animal experiments about the use of synthetic grafts for blood vessel repair in infected war surgical wounds showed a high infection rate and failure of repair, and were followed by local or disseminated sepsis.

Many of war surgical doctrines, International Committee of the Red Cross (ICRC) and other, have forbidden the use of synthetic grafts for vascular repair under war conditions.

Complications related to the use of synthetic grafts and veins are the same as in the large trials. Saphenous vein grafts often show fusiform aneurysm formation and intimal hyperplasia. Small arteries were opened shortly after reconstruction. Long term studies pointed out that venous and synthetic grafts often lead to complications related to formation of aneurysms, especially after the use of venous grafts, in some follow up studies up to 100%.

What makes war vascular surgery different? [4, 5]

The problem of war surgeons is to find material for reconstruction of the vascular injury in war conditions [2, 4, 8] on the spot. When we can perform repair using lateral arterial suture or end-to-end anastomosis there are no problems, but problems occur when we are faced with the need to repair large caliber vascular injury [2, 3, 8].

Very often war surgeons are under pressure related to strategic battlefield situation, time management, tired and overloaded personnel, and availability of transfusion service [3, 4].

Two choices: new material or amputation?

Use of synthetic materials and venous grafts is of limited availability [2, 3].

New material

According to surgical standards, till the Croatian War of Independence only polytetrafluoroethylene (PTFE) was available for surgery of infected wounds and burns.

History

Anterior rectus sheath graft

Coursair and Lam in 1952 performed plastic repair of coarctation of a dog's aorta using the anterior rectus sheath patch. Stanley in 1982 used a tubular graft made from anterior rectus sheath for replacement of part of thoracic aorta in dogs [8]. After angiographic follow up, growing of tubular graft was reported. Aorta showed growth of about 22.25% in six months and tubular grafts of 22.85%. Histology did not show any calcification or rupture. Authors found laminations of graft and cellular proliferation. The inner layer was covered by vascular endothelium, while adventitia like tissue was found on the surface. The same team repeated the experiment and confirmed earlier results. The growth of graft together with host aorta was noted. Again histology showed vascularization of the graft and formation of elements like media and serosa in the growing graft.

Growing possibility was observed in the use of fresh rectus sheath as a patch. Growing possibility in rectus sheath grafts treated with acetone was not observed.

The mechanical, physical and biodynamical characters of the anterior rectus sheath grafts were tested. The results showed that the anterior rectus sheath as a patch is reliable and trustworthy for use as a patch in vascular surgery [6–8]. Later on they stopped with the use of rectus patch on arteries and shifted towards creation of artificial heart valves.

In the Croatian War of Independence the Mobile Surgical Teams were incorporated into the Special Police Forces Units. Very often they operated on the spot close to the line of fire [4, 5], following the Croatian War Surgical Tradition [1]. The war was of low intensity characterized by wide use of high velocity missiles [4, 5]. As War Commander of the Mobile Surgical Teams of the Police Special Forces (SJP-MUP-RH), due to increased number of vascular injuries and surgical repairs, I started with routine use of anterior rectus sheaths as grafts for surgical repair of arteries under war conditions. Before the beginning, the animal experiment has been performed. The Ethics Committee allowed the use of anterior rectus sheath in vascular and congenital cardiovascular surgery. Early and late experimental results confirmed the results pointed out by other investigators in this field.

Table 1 shows the results are totally consistent with the results of Coursair and Lam [8], Stanley and Anagnostopulos [6, 7]. They do not coincide with the

results of Riddez and Vaughan, they used venous and synthetic grafts for surgical repair of war vascular injuries.

A silent period in the available literature of auto grafts in vascular surgery followed. After the last work of Athanasuleas and Sawatari, all the interest was moved to xenografts and polyurethane based prosthesis. Nowadays the focus is on tissue engineered grafts, which means that no new data about rectus sheet grafts are available.

There were no aneurysmal formations, no rupture, no calcifications and no deformations. On the contrary, the covering of the lumen by vascular endothelium, laminations of media, formation of elements of serosa layer and vascularization of the graft and adventitia like tissue has been observed and reported. After the war, the anterior rectus sheath graft was used as a graft in congenital heart surgery with the permit of the Ethics Committee of the University of Zagreb School of Medicine.

Wide use of rectus sheath graft in the field of vascular surgery confirmed the results of the experiments. As can be seen in Table 2, the anterior rectus sheath patch was used 114 times and 70 times as a tubular graft. By repair of arteries widely resected due to molecular stress damage. Reoperation rate due to thrombosis and bleeding should be considered not only as a surgical complication. All the patients were war casualties affected by high velocity missiles and very often in hydrodynamic shock. Molecular distress of the surrounding tissue is also an important factor in analysis of the development of complications. The early surgical reoperation rate should not be compared with rate in non-trauma patients. The patients were not placed on anticoagulant therapy. It is an additional argument for anterior rectus patch grafting as a suitable surgical procedure. No later complications were recorded or reported. It means that after the use of anterior rectus sheath as a patch or tubular graft, anticoagulant therapy is not necessary, which is very important for polytrauma patients under surgical care in the field.

Conclusion

After taking into consideration experimental tests dealing with the use of the anterior rectus sheath as a patch, and after wide war surgical use for repair of vascular injuries, mostly contaminated, and after clinical and histologic follow up, we can conclude that patch or tubular grafts created by using anterior rectus sheath could be a reasonable surgical technique for repair of infected injuries of the great vessels under war conditions.

Positive aspects of using the anterior rectus sheath as patch or tubular graft

- graft biodynamic stability
- autograft
- available in every patient as a part of the body
- applicable on the spot
- does not require anticoagulant therapy
- develops histologic transformation to blood vessel

The graft has been used in cardiac surgery [9].

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