Arterial lesions in osteoarticular trauma of the lower limbs

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OBJECTIVE: *To evaluate in-hospital mortality and limb salvage of a series of patients presenting with arterial injury of the lower limbs complicating an osteoarticular trauma, and to determine any preoperative predictive factors of limb salvage.*
METHODS: *Data of consecutive patients treated between 01/2007 and 12/2017 were retrospectively analyzed. Primary outcomes were in-hospital mortality and limb salvage. Multivariate analysis was performed to assess any variable that could affect limb salvage. P values <0.05 were considered statistically significant.*
RESULTS: *The postoperative course, death occurred in 2 patients Lower limb amputation was performed in 13 cases (15.6%). The main factors predicting limb amputation were the timing of staged surgery, in particular when bone stabilization was performed first (P<0.001), and a delay Data concerning 74 patients with 83 traumatized lower limbs were analyzed. Most vascular lesions were located at the popliteal artery (47, 63.5%). Surgical bone stabilization was performed as a first step in 45 patients (60.8% of cases), followed by a delayed arterial repair. The median time to revascularization was 14.3 hours (range from 2 hours to 6 days). In 29 patients (39.2%) vascular repair and bone stabilization were performed simultaneously. During to limb revascularization longer than 6 hours (P<0.001). The location of injury at the popliteal artery (P=0.005), the presence of infection (P<0.001), and the severe ischemic signs at presentation (P=0.001) also were factors associated with amputation.*
CONCLUSIONS: *The timing of staged surgical repair and the revascularization delay were the main predictor factors of limb salvage.*

KEY WORDS: Osteoarticular trauma, Vascular injury, Limb salvage, Orthopedic trauma

Introduction

Complex vascular injuries of the lower limbs are widely increasing as a result of the widespread of motor vehicles accidents and urban violence. Their association with orthopedic trauma is then quite common, since they could be seen in up to 16% of patients [1]. The most frequent mechanism of vascular injury in bone trauma is contusion[1] due to the crushing or the high impact energy transfer.

These injuries are characterized by an extensive damage to surrounding tissues with high rates of morbidity, mortality and amputation [2-6].

In addition to the orthopedic and vascular lesions, the frequently associated nerve, venous and soft tissue lesions play a major role in the fate of the limb, as well as in the choice of the optimal therapeutic method, that must be urgent and should be undertaken in a multidisciplinary approach [1].

Nevertheless, the surgical management is challenging and still remains open to debate, especially with regard to the optimal timing of the staged surgical repair. Therapeutic options usually include either bone stabilization first, followed by vascular management or ensu-

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ring arterial revascularization first followed by bone stabilization. However, there is no clear consensus about either of these managements.
The aim of our study was to evaluate the results of the management of a series of patients presenting with osteoarticular lower limb traumas and vascular injuries, in terms of mortality and limb salvage, and to determine the preoperative factors that could be predictive of limb salvage.

Materials and Methods

This retrospective study was approved by the local Institutional Review Board.
Data of consecutive patients who required arterial revascularization between 01/2007 and 12/2017 for a vascular injury of the lower limb complicating an osteoarticular trauma were retrospectively collected from medical records and from the operating logbook, and analyzed. Patients who underwent primary amputation without attempted vascular repair were excluded, as well as patients who presented iatrogenic vascular lesions during osteosynthesis of bone trauma, patients who presented severe polytrauma, and patients who had osteovascular lesions caused by gunshot.
Data about the type and location of the osteoarticular and arterial lesions and the time to revascularization were collected. An orthopedic surgeon, a vascular surgeon or a cardiovascular surgeon examined all patients at admission in a multidisciplinary approach, assessing the Mangled Extremity Severe Score (MESS) [7], the signs of leg ischemia, and the hemodynamic parameters. In particular, a shock state (SS) was defined by systolic arterial pressure values lower than 90 mmHg [8].
Doppler ultrasound and CT angiography were not performed systematically. Imaging was performed only when the patient was hemodynamically stable or when the diagnosis of limb ischemia was not clinically clear.
Primary outcomes were in-hospital mortality rate and limb salvage. Secondary outcomes included the occurrence of any in-hospital complications. Statistical analysis was performed using the software SPSS 21. Data were reported as median and range for continuous variables, and frequency and percentages for dichotomous variables. Multivariate analysis was performed to assess any variable that could affect limb salvage. Odds Ratios (OR) with 95% Confidence Intervals (CI) were reported. P values <0.05 were considered statistically significant.

Results

A total of 74 patients with 83 traumatized lower limbs were included in the study. Patients' median age was 39.2 years (range 7-85 years). There were 14 female patients (18.9%).

Table I - *Clinical presentation of the patients in the case seriesanalyzed.*

Ischemic signs	N=74 patients
– Pain	74 (100%)
– Limb hypothermia	66 (89.2%)
– Toe paresis	47 (63.5%)
– Acrocyanosis	27 (36.5%)
– Limb paralysis	12 (16.2%)
– Marbling	18 (24.3%)
Nervous lesions	N=74 patients
– Common peroneal nerve	9 (12.2%)
– Tibial nerve	8 (10.8%)
Minor associated lesions	N=74 patients
– Benign head trauma	5 (6.7%)
– Pulmonarycontusions	2 (2.7%)
– Low grade pneumo/hemothorax	3 (4.1%)
– Controlaterallimbfracture	10 (13.5%)
– Controlateralkneeluxation	3 (4.1%)
– Abdominalcontusions	3 (4.1%)
– Metatarsalfracture	2 (2.7%)
– Thoracic contusions	8 (10.8%)
Venous lesions	N=74 patients
– Popliteal vein	12 (16.2%)
– Collateral popliteal vein	50 (67.6%)
MESS score	N=74 patients
– > 7	34 (45.9%)
– < 7	40 (54.1%)
Osteoarticular lesions	N=83limbs
– Knee dislocation	24 (28.9%)
– Knee dislocation + tibial fracture	7 (8.4%)
– Single tibial fracture	22 (26.5%)
– Multiple limb fracture	30 (36.1%)

*MESS = Mangled Extremity Severity Score

Table II - *Ischemic time of all patients in the case series analyzed, from trauma to revascularization.*

Delay	**Nr. of patients** (%)
< 6 hours	28 (37.8%)
Within[6h-12h]	26 (35.1%)
Within [12h-18h]	5 (6.8%)
Within [18h-24h]	3 (4.1%)
>24 hours	12 (16.2%)

Road accidents accounted for 74.3% of all causes of injuries, while 9 patients had a domestic accident (12.2%). In the remaining 12 cases, the patients were involved either in sports injuries or in job accidents (6 cases each).
In 4 out of 74 cases (5.4%), emergent operation was performed because of severe hemodynamic instability with SS.
The orthopedic assessment of the 83 limbs found 31 knee dislocations (3 of them were associated to a tibial

fracture), 22 fractures of a single segment and 30 multiple fractures (Table I).

Most vascular lesions were located at the popliteal artery (47), 17 involved the superficial femoral artery and 19 involved the tibial arteries. In particular, the arterial lesions included 61 cases of contusions, 11 cases of arterial spasm and 11 cases of arterial sections; 5 of them were complete sections. All patients presented with pain, and most of them had a hypothermic limb (66/83 limbs, 89%). Seventeen patients (22.9%) also had an associated nerve lesion (Table I). The MESS prognostic score was calculated in all patients. Thirty-four had a MESS score greater than or equal to 7 and 40 patients had a score below 7.

A computed tomography angiography (CTA) was requested in 66.2% of the cases before the operation.

Surgical stabilization of bone lesions was performed as a first step in 45 patients (60.8% of cases), followed by a delayed arterial repair. In these cases, the median time to revascularization was 14.3 hours (ranging from 2 hours to 6 days). In 29 patients (39.2%) vascular repair and bone stabilization were performed simultaneously, being the vascular time performed first in 26% of these cases.

Fifty-five patients (72.9%) underwent revascularization within 12 hours from the occurrence of the trauma, 28 of them were treated before 6 hours of ischemia (Table II). Twelve patients (16.2%) had a revascularization after 24 hours. These were mainly patients referred by regional hospitals that were more than 60 km far away.

Arterial restoration by venous bypass using the inverted great saphenous vein was the procedure of choice in 70 limbs (84.3%), Table III. The surgical exploration did not find any arterial lesion but spasm in 11 limbs (13.2%), which was restored in all cases by the passage of a Fogarty catheter. Finally, a direct arterial suture was performed in two limbs (2.4%) with an incomplete section of the superficial femoral artery and a complete section of the subarticular popliteal artery respectively.

In 24 cases (32.4%), fasciotomies were also associated to surgical revascularization.

In-hospital complications

During the postoperative course, death occurred in 2 patients. One case was a 57-year-old pedestrian who was struck by a motorcycle and suffered a femoral diaphysis fracture with interruption of the arterial flow in the superficial femoral artery at its mid third (Fig. 1). A femoral-popliteal venous bypass with fasciotomy of the 3 muscular compartments of the leg was performed. Unfortunately, the vascular state of the leg did not improve and infection of the wound occurred, therefore transtibial amputation had to be performed at 6th postoperative day (POD). Secondly, a transfemoral amputation was performed 15 days later for progression of the infection but a septic shock required his transfer to the intensive care unit. The patient finally died on POD 47 due to a refractory septic shock.

The second case was a 39-year-old motorcyclist who was struck by a car and suffered a fracture of the tibial plate, a fracture of the two bones of the left leg, a left hemothorax and abdominal contusions. He landed at the emergency department in hemorrhagic SS under noradrenaline with Hemoglobin levels at 5g/dl and ischemia of both lower limbs. A popliteal-posterior tibial venous bypass and a popliteal-anterior tibial venous bypass were performed respectively on his right and on his left leg. Immediate postoperative course was spent in the intensive care unit, where he stayed for two days with deterioration of his hemodynamic and respiratory status. He finally died from a multi-organ failure on POD 3.

During in-hospital stay, there were also 13 cases of infection, 7 bypass thrombosis, 3 hemorrhage, 4 revascularization syndrome and 8 cases of compartment syndrome. Secondary lower limb amputation was performed in 13 cases (15.6%), being in 10 of them a transfemoral amputation and in the remaining cases a transtibial amputation. Amputation was performed after a median of 7 days from the first revascularization procedure (range 3 to 20 POD).

In particular, considering the average post-traumatic revascularization time of 28 hours (range 6-72 hours), amputation was required in 10 out of 20 patients (50%) who had an ischemic time longer than 12 hours. Among the group of patients who had an ischemic time lower than 6 hours (28 cases), only 2 patients required a secondary amputation (37.8%). In the remaining case of amputation, the arterial restoration had been performed within 6 to 12 hours from the trauma.

Table III - *Type of arterial surgical revascularization.*

	Nr. of procedures, % (N=83limbs)
Embolectomy	11 (13.1%)
Direct arterial suture	2 (2.4%)
Bypass	71 (84.5%)
– Femoral-poplitealusing GSV	
Homolateral GSV	2
Contralateral GSV	25
– Popliteal-poplitealusing GSV	
Homolateral GSV	1
Contralateral GSV	11
– Popliteal-PTA	
Homolateral GSV	2
Contralateral GSV	14
– Popliteal-TPT (Contralateral GSV)	7
– Popliteal-ATA (Contralateral GSV)	5
– Femoral-TPT (Contralateral GSV)	2
– Iliac-femoral (Contralateral GSV)	1

*GSV=great saphenous vein; PTA=posterior tibial artery; TPT=tibioperoneal trunk; ATA=anterior tibial artery

Table IV - *Variables associated with the risk of secondary limb amputation. Odds Ratios with each respective 95% confidence interval (CI) are reported. In the last column, P values are also reported. Significant P values are in bold.*

Study Variable	Odds Ratio	95% CI	P value
Age> 50	6.4	0.7-52.2	0.4
Male sex	1	0.2-5.8	0.5
Site of injury at the poplitealartery	1.6	1.1-2.8	0.005
Staged fracture	1.8	0.2-3.8	0.15
Timing of surgery (bonestabilization first)	2.3	1.1-3.5	<0.001
Signs of ischemicseverity	1.6	1.1-2.8	0.001
Presence of infection	1.2	1.1-1.7	<0.001
Presence of associatedvenouslesion	0.9	0.3-3.2	0.4
Presence of associated nervous lesion	2.4	0.6-14.8	0.2
Musculoskeletal decay	1	0.3-3.3	0.5
MESS >7	1.2	0.2-1.9	0.06

Of the 13 cases of amputation, 6 patients had a lesion of the popliteal artery, 4 had a lesion of the superficial femoral artery, 2 had lesions of two tibial arteries and only one case had a lesion of all 3 tibial axes.
The most important factors predicting limb amputation at the multivariate analysis (Table IV) were the timing of staged surgery, in particular when bone stabilization was performed first (p <0.001), and a delay to limb revascularization longer than 6 hours (p <0.001). The location of injury at the popliteal artery (p = 0.005), the presence of infection (p <0.001), and the signs of ischemic severity at presentation (p = 0.001) also were factors associated with amputation.

Discussion

In our study we aimed to evaluate the results of the management of a series of patients presenting with osteoarticular lower limb traumas and vascular injuries, in terms of mortality and limb salvage, and to determine any preoperative factor that could be predictive of limb salvage.
One of the key of our work was the finding of a strong relation between the need of amputation and the delay of arterial restoration of the traumatized leg.
Vascular lesions associated with osteoarticular trauma often occur within the framework of a polytraumatism, which require an accurate assessment about both the systemic and the local conditions [6,9]. However, a complete evaluation of the lesion balance sometimes could be demanding, and it may take longer than expected.
One of the main problems to face, in fact, could be the diagnostic delay that is often encountered in the lesions of the popliteal artery, in which the diagnosis of ischemia may be challenging. In this district, ischemic signs could be often misleading or even absent, but the prognosis can be seriously hampered by the poor arterial collateral network [10]. Indeed, the clinical picture can be straightforward, but not always complete. Pain is a constant sign in these patients, as observed in our series. This sign may be explained by fracture or dislocation, however, if it is of ischemic origin, it differs in persistence despite immobilization of the traumatized limb. The coldness of the limb is an inconstant sign in the early hours of the trauma and often subjective in patients in collapse. In our series, the complete ischemic signs were present in 51% of the population, comparable to the rate of 60% reported by Akula et al. [11].
Nevertheless, the diagnosis of limb ischemia and its management must be fast. The duration of ischemia plays in fact a key role in limb salvage, since diagnostic and therapeutic delay is an acknowledged factor of limb loss [1,12]. Although the time interval between the occurrence of the trauma and the arrival at a referral center is rarely manageable, the time elapsed between arrival at the hospital and the operation can be crucial to improve care. In our series, the average revascularization time was 14 hours. More than 60% of the patients were revascularized after 6 hours of the trauma, more than 20% were revascularized after 18 hours. It is clear that awareness of diagnostic pitfalls can improve outcomes for these patients. As far as surgical management is concerned, the ideal is that the orthopedic and vascular operative procedures are performed in the same operating theater.
In front of a vascular lesion associated with an osteoarticular traumatism, two options are available to the surgeons: either arterial repair before the bone fixation, which minimizes the time of ischemia [13], or bone stabilization before any vascular act to minimize the risk of iatrogenic trauma to bypass surgery [14]. The surgical sequence of the osteovascular traumas is still a subject of debate. According to Cakir et al. [15], in case of unstable fracture the orthopedic procedure is required first, followed by vascular repair. Arguments for early bone stabilization reside in the fact that vascular repair can be dangerously threatened by persistent mobility at the fracture site. Conversely, orthopedic time is sometimes long and may tip the ischemic tissue lesions to irreversibility. Such a risk, in this particular context, dominates the problem for many Authors[16]. This is why the external

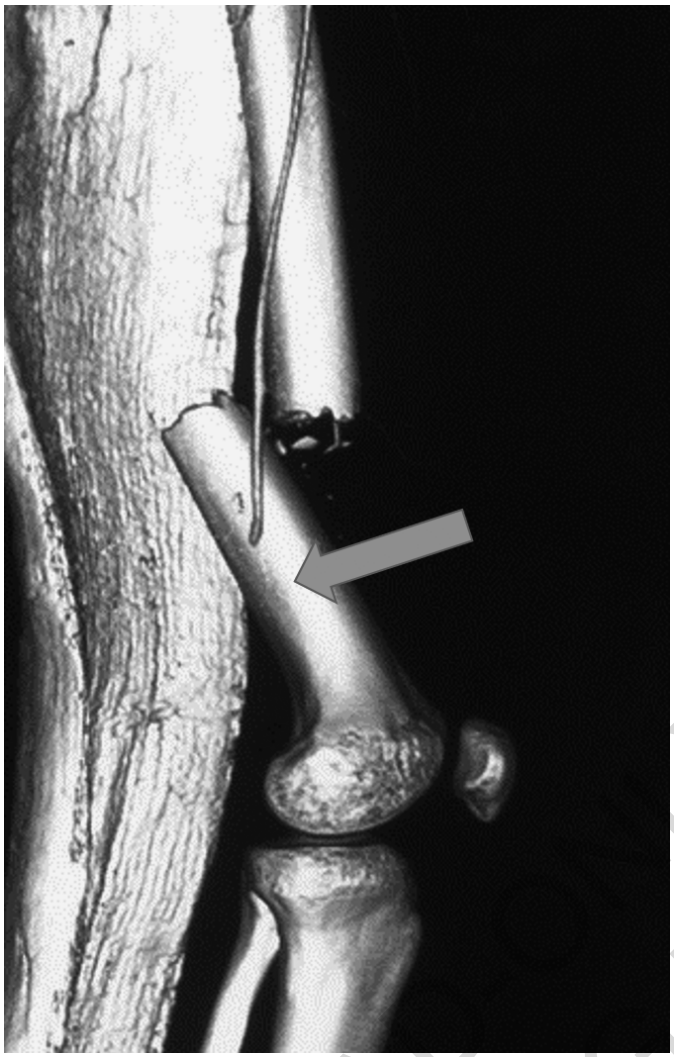

Fig. 1: Three-dimensional reconstruction of a CT-scan showing a femur diaphysis fracture with interruption of the arterial flow in the superficial femoral artery downstream.

fixer is required as a method of stabilization of choice given the speed and simplicity of its implementation. In cases where a first orthopedic surgery is required, the establishment of a temporary shunt can reduce the time of arterial ischemia but most often after alignment of the bone lesion. According to Cavadas et al., the use of an arterial shunt before bone stabilization followed by arterial repair is a priority because this significantly decreases the ischemic time [17].

Several authors such as Glass et al.[12] opt for vascular restoration first when the duration of ischemia has reached the critical threshold of 8 hours. Bone stabilization is achieved only when they ensure the viability of the limb. According to Cakir et al. [15], in the presence of a stable fracture vascular restoration predominates, followed by orthopedic fixation and then angiographic vascular control.

The most common type of revascularization is bypass restoration using autologous great saphenous vein. In our experience, bypass grafting was performed using the contralateral great saphenous vein whenever possible, in order to preserve the venous capital of the traumatized limb considering the high risk of finding an associated deep venous lesion. Associated fasciotomies are performed as soon as a compartment syndrome is suspected. For some authors, fasciotomies can be prophylactic, since they reduce the amputation rate by 6 times if they are performed primary [15]. In our series, fasciotomies were not done in a systematic way because of its tendency to increase chronic bleeding and the risk of infection.

Primary amputation of the lower limb in the context of trauma is a difficult decision especially given the young age of the population. In different studies, the average amputation rate for the lower limb is variable. The comparison of such figures must be done with care, because the series are not homogeneous as the associated lesions differ according to the studies. In an old series by Russell et al.[11], the arteriovenous lesions were severe with muscular involvement in 100% of cases resulting in an amputation rate close to 40%, whereas in the series of Tampe et al, the amputation rate was 20% for patients without musculo-cutaneous disfigurement [19]. Similarly, in our study, patients who underwent a secondary amputation had serious bone, muscle and skin lesions on arrival.

Several scores have been proposed to establish "guidelines" for limb amputation, but the most used is the MESS score, which is considered a high predictor of amputation when is greater than or equal to 7. Nevertheless, none of the different scores used has proved a good specificity with respect to amputation [20]. In our series, the average MESS score was 12 with extremes between 7 and 18 without being at high risk of limb loss. Therefore, it remains difficult to make a primary amputation decision in a young patient based only on a severity score. In the majority of the cases, the attempt to rescue the limb is implemented with knowledge that some prognostic factors exist [10,12].

The time to revascularization remains undoubtedly the most important prognostic element, with a reported cut-off of 6 hours [1,12]. Similarly, in our series the delay to revascularization was highly predictive of amputation.

Some authors therefore emphasize the importance of the surgical sequence on the risk of amputation of the traumatized limb, underlying the need to revascularize first, before stabilization of the bone lesion [12], in order to minimize the ischemic time. Notably, the uni and multivariate analysis of our series showed that when the first sequence was orthopedic, especially when it was performed in another hospital structure, there was a high risk of amputation ($P<0.001$). The interpretation of this result is unequivocally linked to a delay in the revascularization of the traumatized limb.

Signs of ischemic severity are also a major factor in limb loss. In our study, more than half of amputated patients had ischemic severity signs at the arrival. Again, these signs could be closely related to the delay of care.

The site of the arterial injury plays also an important role. Several authors agree that the rate of amputations is greater after lesions of the popliteal artery and of the leg axes, especially in case of coexistent venous and nerve lesions [21]. Musculoskeletal decay and infection also play a major prognostic role [19]. This compares closely to the results of our series, as we found that the location of injury at the popliteal artery and the presence of infection were prognostic factors for amputation.
At the end of this work, our attitude to these traumas is to proceed with limb revascularization as soon as possible, especially when the delay exceeds six hours. Explorations beyond this time limit rarely find their place. When the bone fracture is large, the patients is operated on along with an orthopedic surgeons. The placement of the external fixator pins is performed first and then the arterial revascularization (which often requires knee mobilization for the bypass graft). The setting of the external fixation device is completed at the end of the procedure.
Postoperative death is rarely directly related to vascular injury by haemorrhagic shock, but is mostly related to general associated lesions, severe infection or revascularization syndrome[22], which itself is related to the delay in revascularization. The mortality rate of 2.7% in our population is considered low compared to that reported by other authors, which varies between 5% and 12%[23]. This finding could be explained by the exclusion in our work of severe polytrauma.

Conclusion

Vascular injuries complicating osteoarticular trauma represent a challenging task. The timing of staged surgical repair and the revascularization delay, which in our study were the main predictor factors of limb salvage, significantly affect the outcome. According to our results, investigations and bone stabilization should never delay arterial repair if the ischemic time exceeds 6 hours.

Riassunto

Scopo del lavoro è valutare la mortalità intraospedaliera e il salvataggio degli arti di una serie di pazienti con lesione arteriosa degli arti inferiori a seguito di un trauma osteoarticolare, e determinare eventuali fattori preoperatori predittivi del salvataggio d'arto.
I dati di pazienti consecutivamente trattati tra il 01/2007 e il 12/2017 sono stati analizzati retrospettivamente. Gli outcomes primari sono stati la mortalità intraospedaliera e il salvataggio degli arti. È stata eseguita un'analisi multivariata per valutare qualsiasi variabile che potesse esserre significativamente predittiva di salvataggio d'arto. Valori di P <0,05 sono stati considerati statisticamente significativi.
Sono stati analizzati i dati relativi a 74 pazienti con 83 arti inferiori traumatizzati. La maggior parte delle lesioni vascolari erano localizzate all'arteria poplitea (47, 63,5%). La stabilizzazione ossea è stata eseguita come primo tempo chirurgico in 45 pazienti (60,8% dei casi), seguita da una riparazione arteriosa ritardata. Il tempo mediano di rivascolarizzazione è stato di 14,3 ore (range da 2 ore a 6 giorni). In 29 pazienti (39,2%) la riparazione della lesione vascolare e la stabilizzazione ossea sono state eseguite simultaneamente. Durante il decorso postoperatorio, 2 pazienti sono deceduti. L'amputazione dell'arto inferiore è stata eseguita in 13 casi (15,6%). I principali fattori predittivi di amputazione dell'arto sono stati la tempistica della strategia chirurgia, in particolare modo il rischio maggiore di amputazione si è registrato quando la stabilizzazione ossea veniva eseguita per prima (P <0,001), e un ritardo nella rivascolarizzazione dell'arto superiore a 6 ore (P <0,001). La localizzazione della lesione vascolare all'arteria poplitea (P = 0,005), la presenza di infezione (P <0,001) e la gravità dei segni ischemici alla presentazione (P = 0,001) sono altresì stati associati all'amputazione.
In conclusione, la tempistica della strategia di riparazione chirurgica e il ritardo di rivascolarizzazione sono stati i principali fattori predittivi del salvataggio d'arto.

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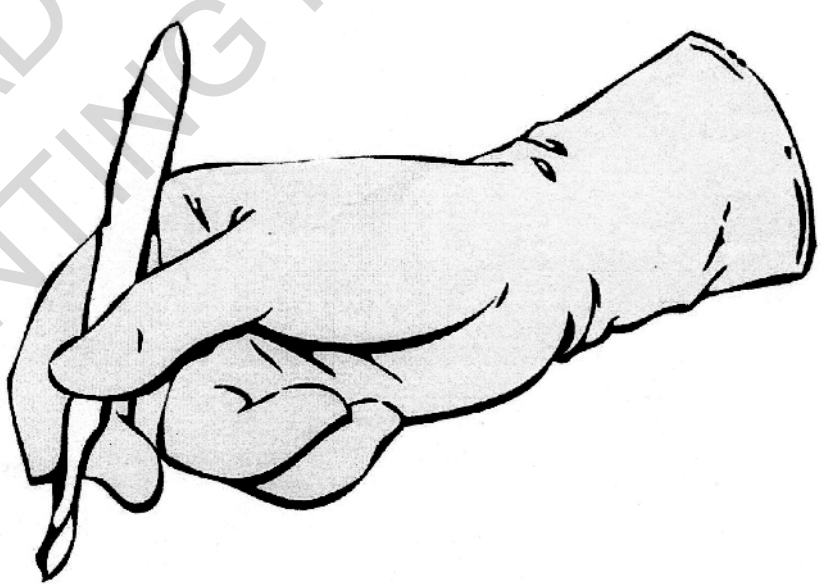
MANUALE DI AUTOAPPRENDIMENTO

ESERCITAZIONI, AUTOVERIFICA E AUTOVALUTAZIONE NELLA PREPARAZIONE ALL'ESAME DI CHIRURGIA GENERALE II E ALL'ESAME DI ABILITAZIONE PROFESSIONALE



CASISTICA DI CLINICA CHIRURGICA