



A sneaky surgical emergency: Acute compartment syndrome. Retrospective analysis of 66 closed claims, medico-legal pitfalls and damages evaluation



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ABSTRACT

Background: Acute compartment syndrome (ACS) is a clinical condition with potentially dramatic consequences, therefore, it is important to recognise and treat it early. Good management of ACS minimises or avoids the sequelae associated with a late diagnosis, and may also reduce the risk of malpractice claims. The aim of this article was to evaluate different errors ascribed to the surgeon and to identify how the damage was evaluated.

Materials and methods: A total of 66 completed and closed ACS cases were selected. The following were analysed for each case: clinical management before and after diagnosis of ACS, imputed errors, professional fault, damage evaluation and quantification. Particular attention was paid to distinguishing between impairment because of primary injury and iatrogenic impairment. Statistical analyses were performed using Fisher's exact test and Pearson's correlation.

Results: The most common presenting symptom was pain. Delay in the diagnosis, and hence delay in decompression, was common in the study. A total of 48 out of 66 cases resolved with the verdict of iatrogenic damage, which varied from 12% to 75% of global capability of the person. A total of \$394,780 out of \$574,680 (average payment) derived from a medical error.

Conclusions: ACS is a clinical emergency that requires continuous clinical surveillance from both medical and nursing staff. The related damage should be evaluated in two parts: damage deriving from the trauma, so that it is considered inevitable and independent from the surgeon's conduct, and damage deriving from a surgeon's error, which is eligible for an indemnity payment.

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Introduction

Acute compartment syndrome (ACS) is a clinical condition that can be caused by several pathological conditions, such as fractures, soft-tissue injuries, burns or circumferential dressings.

The treatment of ACS often comprises plastic surgery, traumatology and other main surgeries, including general or vascular surgery. Furthermore, as plastic surgeons are soft tissue 'experts', they are frequently consulted by colleagues to assess a patient's risk of developing ACS at the injured extremity. Sometimes there is a delay in this professional consultation,

which has negative effects on patient outcome and on the surgeon's therapeutic chances. Consequently, among the various medical and surgical procedures that are the object of litigation, ACS still represents a high-risk situation for both the patient and the healthcare provider. This syndrome develops rapidly from the onset of symptoms to the establishment of irreversible damage, but clinicians may change the pathological evolution of the syndrome by adopting certain strategies. This requires a thorough and up-to-date knowledge of ACS.

The causes of ischaemia in Volkmann's contracture were debated for many decades. Matsen [1] and other authors led to the present unified concept of raised intra-compartment pressure (ICP) inside a fascial or osteofascial compartment, which compromised microcirculatory perfusion, and lead ultimately to macro-circulatory arterial occlusion. This condition, if not immediately treated, can lead to ischaemia and necrosis, with consequent fibrous tissue degeneration of the involved body structures and functional damage. The final result is a fibrous retraction with a variable degree of contracture of the involved muscles and, in extreme cases, amputation of the injured limb is necessary. In some cases, fibrous retraction may cause a compression of nervous structures [2]. A rare complication is acute renal failure caused by myoglobinuria, which can be fatal [3].

Regarding risk factors, ACS particularly affects young people (under 35 years old), because they have stronger fascial structures and more frequently develop high-energy injuries compared with older individuals [4]. The most common cause of ACS is fracture of the tibia: the literature indicates an incidence of compartment syndrome from 2.6% to 9% in tibial fractures [5]. There are several risk factors, which can be divided into two groups:

- Factors that cause reduction of compartment volume: these include burns [6], casts [7], skin [8] and skeletal traction [9], incorrect patient position during operation (lithotomy, hemilithotomy, lateral, supine, Trendelenburg) [10–14], and prolonged immobilisation due to other causes [15].
- Factors that cause increase in compartment content: these include fractures [5], blunt soft-tissue injuries [16], sport/exercises [17], intramuscular haematomas [18], snake bites [19], infections [20], osteotomies [21], vascular procedures [22], intraosseous [23] or intravenous [24] infusions, drugs [25], minor procedures (e.g. punch biopsy [26], electromyography [27]), extravasations of contrast media [28], and haematological diseases [29].

The body sites more commonly affected by the development of ACS are the extremities of the limbs [30]; more rarely ACS develops in the abdomen or in orbital cavities [31].

Clinical diagnosis of ACS is classically based on several elements: a severe pain that is out of proportion to the apparent injury is often the main presenting symptom. The pain is usually increasing and resistant to analgesic drugs, even if in some cases it may be obfuscated by pain deriving from associated injuries [32], such as a fracture. Pallor, paresthesia, paresis, pain on passive flexion or extension, palpably swollen or tense compartments and finally pulselessness may appear, particularly when compartmental ischaemia has already developed. Detection of worsening symptoms depends on careful and sequential clinical examination, which should be ideally performed by the same physician.

A useful technical examination to improve diagnostic capability is the measurement of ICP, which normally varies from 0 to 8 mmHg. The first clinical symptoms of ischaemia appear at an ICP of 20–30 mmHg. At an ICP of 30–33 mmHg the fascial membranes usually reach the maximum tolerable stretch. Some surgeons consider an ICP of greater than 30 mmHg in any compartment to be an indication for fasciotomy, while others consider a threshold for

surgical intervention is when ICP is within 30 mmHg of the patient's diastolic blood pressure [33]. Even if various examinations to aid clinical diagnosis of compartment syndrome are available, measurement of ICP is still the most useful method. Nevertheless, recent studies have demonstrated that ICP data, particularly single readings, must be interpreted in view of clinical findings, and clinical assessment is still the diagnostic cornerstone of ACS [34].

From the medico-legal point of view, the evaluation of Personal Injury due to ACS is still an important concern. The first issue that any evaluations system has to solve is to define the object it wants to evaluate. Damage to the patient may be both economic (e.g. lost wages, past and future healthcare expenses) and non-economic (e.g. psycho-physical harm, severe pain, emotional distress, reduced enjoyment of life).

In the USA, the American Medical Association (AMA) defines impairment as "an alteration of an individual's health status; a deviation from normal in a body part or organ system and its functioning" and disability as "an alteration of an individual's capacity to meet personal, social, or occupational demands because of an impairment". In Italy, impairment and disability are blended in a unique concept, called "biological damage", which is defined as "injury to physical or mental integrity of the person susceptible to medico-legal assessment". It includes physio-anatomical and psychological abnormalities and their repercussions on daily activities and the individual's capacity to meet personal-social demands.

There are many systems for measuring impairment, including scientific society guidelines (e.g. AMA) and workers' compensation programmes. The ratings shown in this paper are based on the Luvoni–Bernardi–Mangili Guide [35], which provides structured evaluation categories aimed at reducing variability in impairment ratings in Italy. Similar to other guidelines, it is a standardised tool that can be used to convert medical data into numerical values (whole-person impairment percentages).

The rating of impairment/disability due to ACS can be difficult because ACS is a complication that often develops from a previous injury. The rating is therefore in two parts: damage deriving from the primary injury, so that it is considered inevitable and independent from medical conduct, and damage deriving from physician error.

Therefore, in evaluating damages the medical expert should attempt to reconstruct the pre-existing condition, its natural evolution and consequences, based on reasonable medical probability, and give it a separate percentage impairment rating. This should be deducted from the whole-person impairment to arrive at the differential (apportioned) rating that is attributable to the ACS.

This distinction is very important because it is used to share out the burden of compensation (i.e. the so-called "apportionment"; in Italy "differential damage").

Materials and method

Out of 1859 cases of claims in surgical specialties that were analysed by the Chair of Legal and Insurances Medicine of the University of Milano-Bicocca from 2000 to 2010, 66 completed and closed cases were studied. Each case was a patient who developed an ACS after a trauma or a major operation.

The following factors were analysed for each case: age of patient, aetiology, time between trauma/operation and onset of presenting symptoms, time between onset of presenting symptoms and fasciotomy, patient complaints and type of error, if any, and the presence or absence of the misconduct ascribed to the surgeon and the liability profile. The informed consent and any related protests were also considered.

Aesthetic and functional impairment were defined and evaluated as a percentage reduction of ability to work and of capability to maintain a normal life in terms of familiar relationships, psychological aspects and sexual relations.

Traumatic cases (T-ACS) were defined as cases that related to a sport injury, fall or motor vehicle collision. Postprocedure cases (PP-ACS) were defined as those that developed following a surgical intervention unrelated to compartment syndrome or traumatic injury.

Categorical data were analysed using a two-tailed Fisher's exact test. Correlations for continuous variables were performed with Pearson's correlation coefficient. Whole-person impairment evaluations were based on the Luvoni–Bernardi–Mangili guide (Table 1).

Results

The case series comprised 48 males (aged 4–60 years), and 18 females (aged 12–83 years). Out of 66 cases, 42 were traumatic ACS (T-ACS) and 24 were postprocedure ACS (PP-ACS) (Table 2). Globally, the most involved specialty was traumatology, but among PP-ACS cases vascular surgery specialty was most common ($n = 12$).

Half of the cases involved the leg and in most of cases the injury was caused by an accident (Table 3). In 22.7% ($n = 15$) of cases, ACS involved the thigh region and all of these were postprocedure cases. In 13.6% ($n = 9$) of cases, ACS occurred at the forearm, always deriving from an accident, while in another 13.6% ($n = 9$) of cases, ACS involved the arm region. All bilateral cases ($n = 12$) were

Table 2

Aetiology of ACS cases.

Aetiology	Number (%)
Accident	42 (63.6)
Post-elective surgery (PES)	24 (36.4)
For specialty	
Vascular surgery	12 (18.2)
Orthopaedic surgery	6 (9.2)
Skin traction	3 (4.5)
Transsexual surgery	3 (4.5)

PP-ACS type (Table 3). A mild positive statistical correlation was found between the onset of presenting symptoms and the feasibility to make a correct diagnosis (Pearson correlation: 0.436, $p < 0.001$).

A total of 48 out of 66 claims were resolved with an imputed damage to the surgeon: all resulted in an indemnity payment. In 32% of cases ($n = 21$), there was an appropriate diagnosis, but surgical treatment was considered to be executed with a too long and unjustifiable delay (Table 4); in 15 cases (23%) the error consisted of a misdiagnosis; indeed pain caused by ACS was often undervalued and confused ($p < 0.01$), and primary symptoms had a strong statistical correlation with a guilty outcome ($p < 0.0001$, Table 5). In half of the cases the early presenting symptom was pain, while in the remaining cases it was an evident and palpable tension of the involved region ($n = 27$) and less frequently paresis ($n = 6$) (Table 5). In all PP-ACS cases, guilt was individuated and

Table 1

Reference values of permanent impairment (whole-person impairment percentages according to Luvoni–Bernardi–Mangili Guide [35]).

			Biological damage (%)	
			Dominant limb	Non-d. limb
Upper limb	Shoulder	Ankylosis of scapulohumeral joint		
		With immobility of the scapula	30	25
		With normal mobility of the scapula	25	20
		ROM – 1/2	13	10
		ROM – 1/3	9	7
	Elbow	ROM – 1/4	7	5
		Ankylosis in flexion	40	35
		Ankylosis from 75° to 110°		
		With semi-pronated forearm	25	10
		With normal pronosupination	20	15
		Ankylosis in extension		
		With semi-pronated forearm	30	25
		With normal pronosupination	25	20
		ROM (flexo-extension) from 170° to 45°		
		With semi-pronated forearm	7	5
	With normal pronosupination	5	3	
	Radiocarpal joint	Ankylosis in extension		
		With semi-pronated forearm	15	12
		With normal pronosupination	12	10
ROM – 2/3		10	8	
ROM – 1/2		8	6	
ROM – 1/3		6	4	
ROM – 1/4		4	2	
Lower limb	Hip	Ankylosis of coxofemoral joint with extended limb	40	
		ROM**: flexion < 90°, abduction < 15°	30	
		ROM: flexion < 45°, abduction < 15°	12	
	Knee	Ankylosis in extension	18	
		ROM (flexo-extension) from 180° to 140°	18	
		ROM (flexo-extension) from 180° to 120°	12	
		ROM (flexo-extension) from 180° to 90°	6	
	Tibiotalar joint	Ankylosis (90)°	12	
		ROM – 2/3	10	
		ROM – 1/2	8	
		ROM – 1/3	4	
		ROM – 1/4	2	

Table 3
Analysis of ACS casuistry based on site of injury and aetiology.

Site of injury	Number (%)	Unilateral (aetiology)	Bilateral (aetiology)	Fisher's exact test
Leg	33 (50)	27 (accident)	6 (PES)	p -value < 0.05
Thigh	15 (22.72)	9 (PES)	6 (PES)	Not statistically significant
Arm	9 (13.64)	9 (6 accident/3 PES)	0	Not statistically significant
Forearm	9 (13.64)	9 (accident)	0	p -value < 0.05
Total	66	54	12	Not statistically significant

Table 4
Errors ascribed to surgeons in the case series.

Type of error	Number (%)
Treatment delay	21 (32)
Misdiagnosis	15 (23)
Erroneous choice of operation	6 (9)
Technical surgical mistake	3 (4.5)
Erroneous patient position during operation	3 (4.5)
None	18 (27)

Table 5
Distribution of guilty cases in relation to aetiology, site of lesion, presenting symptoms and fasciotomies.

	Individuated guilt	Not individuated guilt	Fisher's exact test
Aetiology			
Accident	24 (36.3)	18 (27.3)	p -value < 0.0001
Post-elective surgery	24 (36.3)	0	
Site of lesion			
Unilateral	36 (54.5)	18 (27.3)	p -value < 0.0001
Bilateral	12 (18.2)	0	
Presenting symptom/sign			
Pain	30 (45.5)	3 (4.5)	p -value < 0.0001
Tension	12 (18.2)	15 (22.7)	
Paresis	6 (9)	0	
Fasciotomies			
Performed	27 (40.9)	18 (27.3)	p -value < 0.001
Not performed	21 (31.8)	0	

showed a significant correlation to the surgeon's mistakes ($p < 0.0001$).

The huge average total payment was \$574,680 (Table 6). From the differential evaluation of functional and aesthetic permanent impairment, the most significant part of damage could be referred to as iatrogenic (ranging from 12 to 75% of physical or mental integrity), with an average indemnity payment of \$394,780, while the part due to primary injury resulted in an average payment of \$179,900.

Discussion

This retrospective analysis of presented cases shows that in ACS there was usually only one of the classical symptoms and it was

Table 6
Analysis of whole permanent impairment and its components.

Average functional and aesthetic permanent impairment	Range of % of impairment for the whole person (average)	Range of indemnity payment expressed in US dollars (average)
Due to primary injury	3–70 (21.65)	5610–884,030 (179,900)
Due to iatrogenic error	12–75 (36.06)	65,480–920,030 (394,780)

often underestimated or confused with other injuries. Therefore, waiting for the onset of all the typical symptoms of ACS appears censurable. The main early symptom was pain, which was described as intense, progressive and intolerable. It is very important to conduct a careful clinical examination before prescribing analgesic therapy because administration of this therapy may lead to a diagnostic delay.

In this study, none of the physicians had a manometer available for ICP measurement; therefore hospitals may also have a censurable role, not only for shortage of staff, but also for organisational issues, such as unavailability of instrumental machines, which may cause diagnostic delay.

Unfortunately, diagnostic delay remains the most common cause of patient aggravation [5]. Bhattacharyya et al. [36] found that the most prominent risk factor for an indemnity payment was a delay before fasciotomy, particularly when performed later than 8 hours from the time of presentation of the first symptom. In our study, treatment was delayed in 21 out of 66 cases and 15 cases were misdiagnosed and did not even lead to fasciotomy. Early-onset symptoms were associated with an easier diagnosis and, consequently, fasciotomies were performed more rapidly (Pearson correlation: 0.436, $p < 0.001$). Another important observation is that all bilateral cases ($n = 12$, 18%) were post-procedure. It is therefore recommended that all patients who undergo major orthopaedic or vascular surgery receive comprehensive postoperative care and are monitored carefully. Nurses should be informed about ACS as a possible postoperative complication and should be educated to identify quickly a local worsening that is indicative of ACS.

Shadgan et al. [37] analysed an ACS case series where 55% of legally completed cases had an unfavourable outcome for involved physicians and 70% of patients had a permanent physical disability. In the current study, only in 27% ($n = 18$) of cases was the surgeon considered not guilty because he promptly identified the developing ACS and quickly performed fasciotomies, particularly within 3 h from the onset of symptoms.

Regarding compensation, Bhattacharyya [36] reported that the average indemnity payment for ACS cases was \$426,000, which is much higher than the average orthopaedic indemnity payment of \$136,000; however, there was no clear distinction between "primary" damage and damage due to ACS. This distinction is essential because iatrogenic damage should be evaluated taking into account that possible impairing consequences would have occurred anyway. Indeed in 18 out of 66 cases in the current study, fasciotomies were performed quickly, but an average biological damage of 27% (range 5–70%) still occurred.

In a few cases, the initial pathological condition and compartment syndrome involve different body regions, so the distinction is easy. Conversely, in the majority of cases the two pathological events involve the same body site, with overlapping of sequelae. The sequelae of the primary event should be estimated according to the initial pathological condition and its average evolution, taking into account patient age and health status. The evaluation of ACS sequelae should instead include the following factors: the speed of presentation of symptoms that may arouse suspicion of

ACS; the frequency of clinical controls and the adequacy of diagnostic-therapeutic strategies to assess the skill and behaviour of the physician; and the time between onset of symptoms and fasciotomies, to verify if there was a prompt or belated treatment (in the current case series, all fasciotomies performed later than 3 h from the onset of symptoms were considered censurable).

Conclusion

In the case of ACS, it would be useful to conduct a “differential evaluation” of personal damage, which essentially consists of a prognostic judgement of the impairment that would have occurred, even if correct and prompt treatment had been administered, and that should not be considered for compensation. In our study, the average total indemnity payment of \$574,680 was composed of two parts: 31.3% was due to primary injury, while the remaining 68.7% was imputed to ACS sequelae and therefore deserving of compensation. Given that errors of diagnosis of ACS are preventable through continuous monitoring of the patient, we should always keep in mind that this type of iatrogenic injury often represents an avoidable cost. This current study is a further step in the analysis of malpractice claims. Publications of professional liability claim case series are currently lacking [38], even though 99% of the physicians who belong to high-risk clinical specialties and 75% of those at low-risk incur a complaint at least once before they reach the age of 65 years.

Conflict of interest

None.

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