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An abdominal challenge: the compartment syndrome

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Introduction

Compartment syndromes have been described since the 19th century German surgeon Richard von Volkmann published his views on the consequences of ischaemia in muscular regions (1). Reduced vascular supply to such muscular compartments in the extremities could either be due to external or internal raised pressure, and eventually may induce muscle contractures (2). Pathophysiologic mechanisms responsible for these ischaemic contractures became apparent when pressures in confined body systems could be measured with adequate accuracy. Such measurements were first reported in the 18th century by Stephen Hales for blood pressures in horses (3) but became much more accurate at the end of the 19th century when the Italian investigator Scipione Riva-Rocci deviced a new type of sphygmomanometer (4), which is still in use today (5).

In France and Germany different scientists were also interested in pressure measurements. Etienne-Jules Marey (1830-1904) was particularly interested in the registry of various types of physical parameters (Fig. 1), in particular pulse frequency (6) and heart sounds (7), but also intra-thoracic and intra-abdominal pressures (8). Equally in Paris, in the laboratory of Claude Bernard, did Paul Bert (1833-1886) measure pressures by using tubes inserted in the trachea or the rectum, and ascertain an elevated intra-abdominal pressure in case of diaphragmatic descent (9). In Germany too, intra-abdominal pressures were investigated, not only through tubes in the rectum (10), but also in the bladder (11) or the uterus (12).

It now became apparent that intra-abdominal pressure (IAP) could vary according to certain physiopathologic conditions such as ascites (13) or weakness of the abdominal muscles (14). Inversely high pressures in the abdomen could result in major physiopathologic consequences.

In 1911 the in Harvard educated physician Haven Emerson (Fig. 2) showed that forcefully raised IAP in dogs induced fatal cardiovascular collapse (15), while evacuation of ascites in clinical patients resulted in cardiac recovery (15).

Cardiovascular impairment as a result of raised IAP now also became important for surgeons (16) who tried to leave the abdomen open in case of extensive abdominal trauma or operations. The British surgeon sir Heneage Ogilvie described the advantages of laparostomy in abdominal war wounds, and used cotton cloth impregnated with vaseline as an abdominal dressing to allow later re-epithelialisation by covering the wound with split thickness pitch grafts (17).

Indeed forceful closure of an abdominal wound in case of congenital omphalocele (18) or wound dehiscence (so-called "abdominal blow-out") (19) proved to be a cause of death in many such patients and lead anaesthesiologist M.G. Baggot from Dublin in 1951 to advise surgeons to leave the abdomen open and covered with dressings (19).

Meanwhile intravesical pressure measurements became common use in patients on the intensive care (20), and were correlated with the effects on multiple organ function in critically ill patients (21).

So, what are at present the important factors, directing laparostomy and intensive care surveillance in these surgically critical patients?

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Fig. 1 - Etienne-Jules Marey (1830-1904) in his laboratory.

Fig. 2 - Haven Emerson (1874-1957).

Firstly, let us define exactly what we understand under raised intra-abdominal pressure. After a first grading proposal of J.M. Burch et al. in 1996 (22), a new grading system of intra-abdominal pressures has been accepted by the WSACS at the last Consensus Conference of the World Congress of Abdominal Compartment Syndrome in March 2007 (23). This grading system now follows the recently accepted pressure values (23):

- grade I: IAP 12-15 mmHg;
- grade II: IAP 16-20 mmHg;
- grade III: IAP 21-25 mmHg;
- grade IV: IAP > 25 mmHg.

This grading is particularly important not only because of the actually rising prevalence of this disease on the ICU's but more importantly because of its surgical indications. Indeed, when in the first place one looks at recent multi-center epidemiologic investigations, intra-abdominal hypertension, defined as an intra-abdominal pressure equal or more than 12 mmHg, appears to be present in 51% of all critically ill medical and surgical intensive care patients (24), while abdominal compartment syndrome, defined as pressures equal or more than 20 mmHg and combined with one or more organ failures, proves to be present in 8% of such patients (24) (Fig. 3).

Moreover, grading does correlate with clinicopathologic stadia of the inflammatory response that immediately follow the initial injury or operation (25). The association of multi-organ failure and raised intra-abdominal pressure not only is a prerequisite to define intra-abdominal compartment syndrome (ICS) (23), it does lead to concomitant and important cardiac, respiratory, renal and cerebral deficiencies, whether these may be the cause or the result of the ICS (26). The physiopathology of these multiple organ failures have in the last decades been well described (27-32). In the last years it has become apparent that intensive medical and surgical treatment should be instaured before or at the early onset of the intra-abdominal compartment syndrome. Only then can mortality or disabling morbidity be averted (33).

Two independently predictive factors thereby proved of life-saving importance (33), namely prevention or reduction of massive fluid resuscitation (34) and decompression of the abdominal cavity, so-called temporary abdominal closure or TAC (35). Leaving the abdominal cavity open was already recognized necessary in the paediatric treatment of omphaloceles (36), but in adults proved equally beneficial in case of complex aortoiliac procedures (37). Systematic recording of intra-abdominal pressures in critically ill patients have now lead to systematic decompressing relaparotomies that proved to be live saving in grade III and IV ICS scoring system (38). Surgeons adapted their technique of temporary abdominal closure during the last decade.

In the 1980's a zipper system (39) or fascial mesh closure (40) was mostly utilized to give mo-

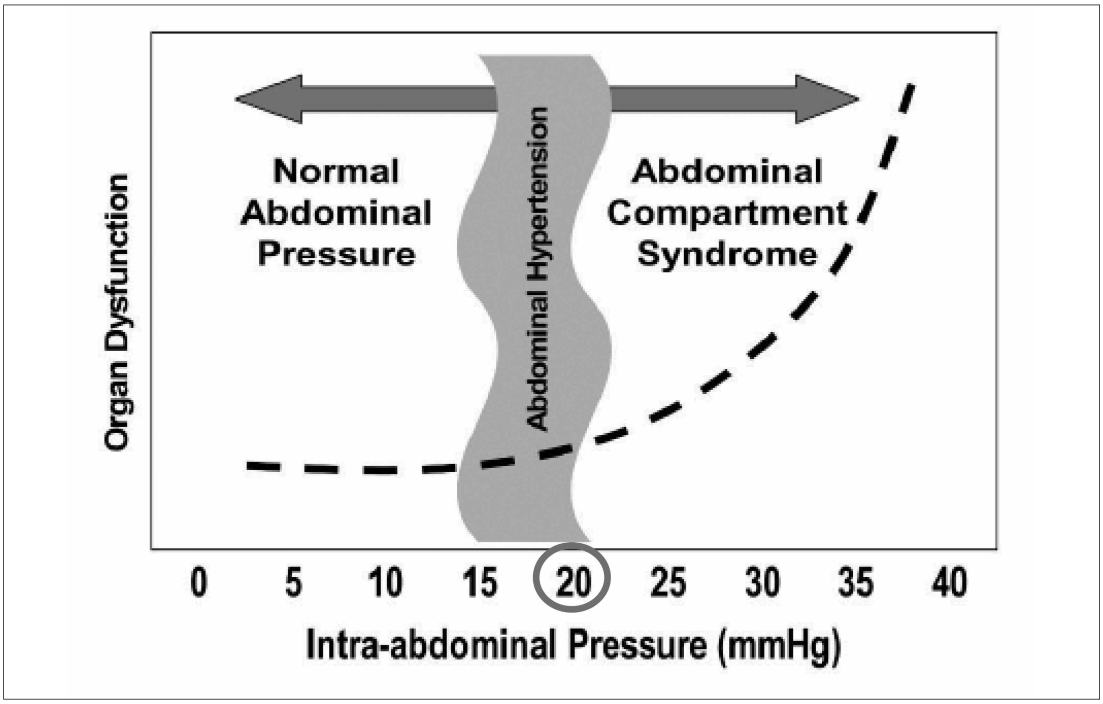

Fig. 3 - Relation between intra-abdominal pressure and clinical syndrome.

re space to the dilated or infected viscera (Fig. 4). After repeated relaparotomies and visceral recovery a definitive abdominal closure was realized by secondary suture, whether or not combined with definitive fascial mesh reconstruction (41). When the deleterious effects of highly raised intra-abdominal pressure became apparent, laparostomy with other dressing systems were investigated (42), at first the Bogota bag, later the VAC system.

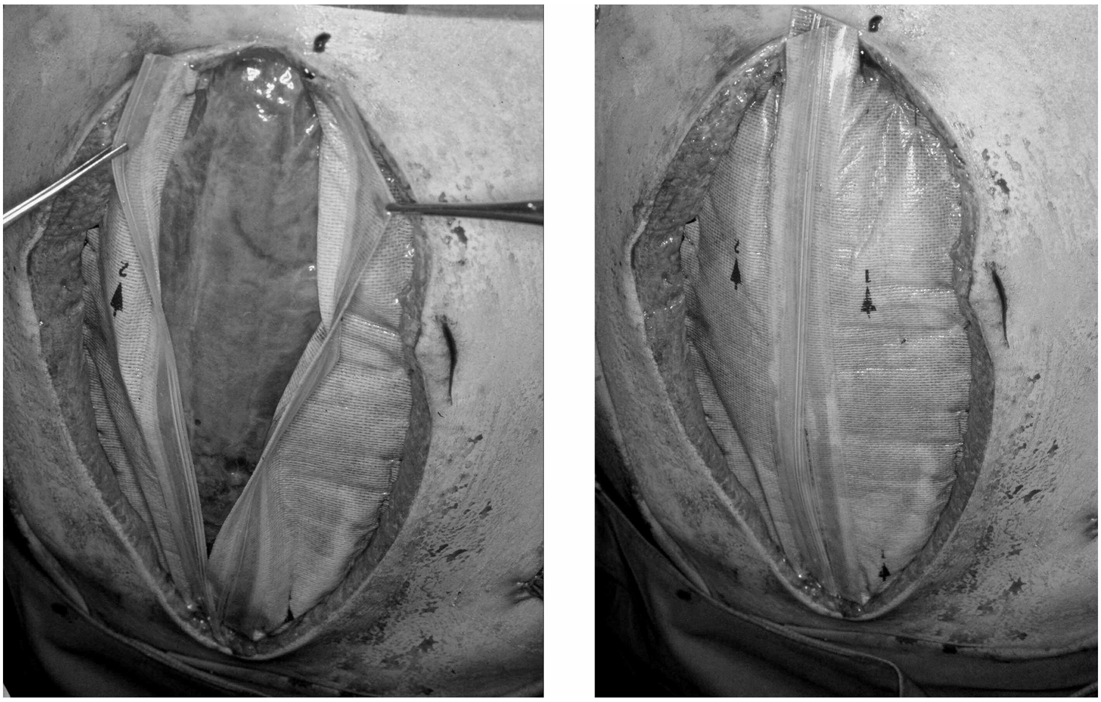

Fig. 4 - Laparostomy with zipper in place.

The Bogota bag consists of a simple 3 liter solution polyvinyl bag, that is sutured to the fascial edges and allows the intestines and omentum to extrude outside the peritoneal cavity (43). The VAC system has been used in the last three years by our and other's teams because of its more beneficial effects on wound closure, resulting in earlier hospital discharge (44) (Fig. 5). The system consists of a vacuum sealed device attached to the abdominal wall that first is covered with sterile sponges, and subsequently aspirates fluids from the peritoneal cavity and oedematous viscera, thus reducing abdominal volume and intra-abdominal pressure (45).

Results of both Bogota bags and VAC systems have been reported and prove to reverse general pathophysiological complications and to reduce intensive care stay periods to virtually half the otherwise lengthy stay of such patients (46). Abdominal distension is often reversed spectacularly and particularly cardiovascular symptoms and renal failure recover significantly more swiftly (47).

Remains the problem of ultimate closure of the abdominal wall defect, once the dressing devices have become superfluous. Various types of plastic reconstruction have been employed, from muscular flap reconstructions to the use of double surface mesh types, that may cover the muscular defect (48). The most well-known is a polypropylene mesh (Prolene® or Marlex®) that provides a strong fascial substitute with excellent ingrowth characteristics and quite resistant to infection (49). An alternative, though more expensive, is a polytextra-fluoroethylene mesh (ePTFE, Gore-Tex®), whether or not combined with an extra fascial layer of polypropylene (Dual Mesh®). Another alternative consists of a cellular human dermis (Alloderm®), however also quite costly (26,38 $/cm^2$).

A totally different abdominal closure approach consists of expanding the abdominal wall either by means of a tissue expander (50) or external oblique muscle separation (51). Either of these techniques may be combined with the application of a polypropylene mesh (52).

At our clinic, as in other's, local or distant flaps are frequently used to cover the abdominal wall defect, especially when tissue coverage of the synthetic mesh is inadequate: either vascularised or free flaps may be used, the last particularly in case of extensive defects (53). Results with muscular flaps have been satisfactory, in particular in case of enterocutaneous fistulas that benefit from definitive coverage (55).

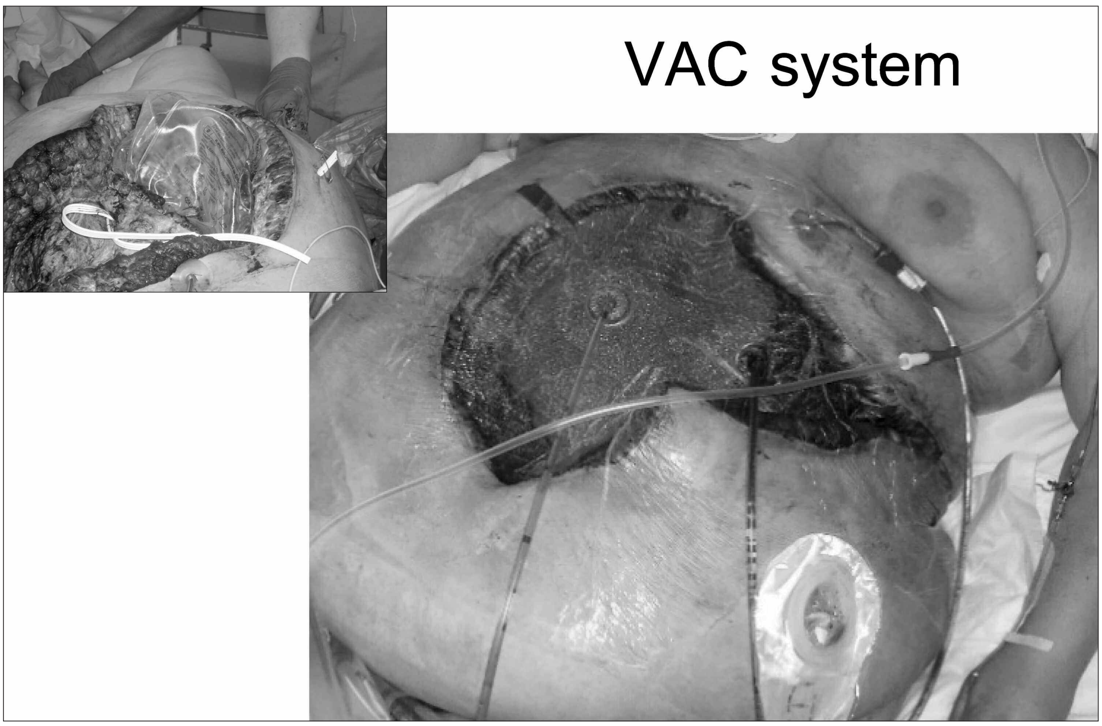

Fig. 5 - Laparostomy combined with VAC system.

Conclusion

Open abdomen techniques with various systems of temporary abdominal dressing closure, have prevented, when performed sufficiently early and adequately, intra-abdominal hypertension and its complications.

By allowing the abdominal content to expand in proportion to existing intra-abdominal pressures, visceral organ perfusion is maintained or restored, preventing a frequently fatal multi-organ failure syndrome.

The contribution of such open abdomen technique has become one of the greatest advances in abdominal and trauma surgery in recent times.

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