

Incisional Hernias with Loss of Abdominal Domain: A New Look to an Older Issue or the Elephant in the Living Room. Literature Review

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Abbreviations:

IH: Incisional Hernia;
LOD: Loss of Abdominal Domain;
IHV: Incisional Hernia Volume;
ACV: Abdominal Cavity Volume;
IAP: Intra – Abdominal Pressure;
IAH: Intra – Abdominal Hypertension;
ACS: Abdominal Compartment Syndrome;
PPP: Preoperative Progressive Pneumoperitoneum;
BTX: Toxina Botulinică (Botox; Dysport);
PP: Plateau Pressure;
PEEP: Positive End Expiratory Pressure;
Cab: Abdominal Compliance.

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Rezumat

Herniile incizionale cu pierderea dreptului la domiciliu: o nouă abordare a unei vechi probleme sau elefantul din sufragerie. Revizie a literaturii

Hernia incizională (HI) este un defect postoperator la nivelul peretelui abdominal prin care conținutul cavității peritoneale, acoperit de seroasa peritoneală, se exteriorizează sub piele. HI sunt entități clinice unice datorită diferențelor de complexitate anatomică dar și datorită comorbidităților asociate și istoricului chirurgical. Pe măsură ce cresc în dimensiuni, evoluția naturală spre complicații este aproape regula. Obiectivul acestui studiu este de a reevalua impactul formelor de hernie incizională cu pierderea dreptului la domiciliu asupra peretelui abdominal înainte dar și după reconstrucția acestuia. Absența anatomică și funcțională a liniei albe conduce la o serie de alterări musculare, patologice cronice respiratorie și digestive precum și la probleme psihosociale. Asocierea scăderii presiunii intra-abdominale (PIA) este un factor agravant al acestor tulburări. În timpul și după reconstrucția peretelui abdominal, reintroducerea forțată a viscerelor într-o cavitate peritoneală nepregătită conduce la creșterea brutală a volumului cavității și implicit a PIA cu implicații fiziopatologice severe, uneori mortale. Pentru o reconstrucție parietală optimală și sigură peretele abdominal trebuie augmentat prin atingerea următoarelor obiective: reducerea volumului conținutului sacular; îmbunătățirea complianței, lărgirea volumului conținătorului. Mai

mult, sunt necesare cunoștințe privind managementul local și sistemic al ansamblului de modificări, evaluarea pacientului prin examen computer tomografic, monitorizarea PIA, a presiunii de platou și a presiunii expiratorii pozitive. Obiectivele pot fi atinse prin optimizarea sistemică cu ajutorul unei echipe multidisciplinare, prin utilizarea pneumoperitoneului progresiv preoperator (PPP) și /sau a toxinei Botulinice la care se adaugă reconstrucția peretelui abdominal prin tehnici de separare a componentelor întărite de material protetice adecvate situație clinice și anatomice.

Cuvinte cheie: hernie incizională, pierderea dreptului la domiciliu, insuficiență respiratorie, presiune intra-abdominală, hipertensiune intra-abdominală, sindrom de compartiment abdominal

Abstract

Incisional hernia (IH) is a postoperative defect of the abdominal wall through which the contents of the peritoneal cavity are externalized beneath the skin in a peritoneal sac. IH differs in anatomic complexity, but also in its associated comorbidities and surgical history. As IH enlarges, complications occur and these become part of its natural history. The goal of the study is to review the impact of loss of domain upon abdominal wall before and after abdominal wall reconstruction. The absence of anatomical and functional linea alba leads to a combination of muscular disturbances, chronic respiratory and gastrointestinal conditions, and psychosocial issues. The pathophysiological changes are also due to the decrease of the intra-abdominal pressure (IAP). During repair, the sudden reintroduction of the viscera into an unprepared cavity leads to a sudden increase in cavity volume and an increase in IAP with fatal pathophysiological implications. For an optimal repair, preoperatively, the abdominal wall must be augmented by achieving the following objectives: reducing the volume of the sac contents, optimizing compliance, enlargement of the container. At the same time, for the optimal repair, the following must be taken into account: increased knowledge about this condition to manage systemic and local changes, CT scan evaluation, monitoring IAP, plateau pressure (PP), and Positive End Expiratory Pressure (PEEP). In conclusion, the goals can be achieved by systemic optimization with a multidisciplinary team, using Preoperative Progressive Pneumoperitoneum (PPP) and/or Botox (BTX), and abdominal wall reconstruction through a mesh with augmented component separation technique.

Key words: incisional hernia, loss of abdominal domain, respiratory failure, intra-abdominal pressure, intra-abdominal hypertension, abdominal compartment syndrome

Introduction

An incisional hernia (IH) is defined as a postoperative, abnormal weakness or orifice in the abdominal wall, through which, normally contained viscera, always enveloped by a serous sac, protrude beneath the skin (1,2). Despite the considerable improvements in surgical know-how (innovations, suture materials, suturing techniques, mesh, and laparoscopy), the incidence of incisional hernia, recurrences, and complications remains

high. The frequency of these appears to be on the rise due to more complex, extensive surgeries in an older, higher risk patient group, an increasing population, and longer life expectancy. All these factors emphasize the fact that the topic is one of major medical and economic importance (3,4). We propose in this study to review recent literature in order to update some important concepts regarding definition of loss of domain, pathophysiology of the anatomical disturbances, and the consequences of the unprepared

abdominal wall reconstruction upon respiratory function and intra-abdominal pressure.

Materials and Method

The authors conducted a research through electronic databases: PubMed, Scopus and Web of Science using the following search formula: “(incisional hernia OR ventral hernia) AND (loss of domain)”. Three inclusion criteria were applied: the articles must be available full text, written in English and published no more than 10 years ago. The references of the selected papers were also checked for other relevant material. The resulting references were included in the current review, focusing on loss of abdominal domain in incisional hernia. In the end, a total number of 28 articles were included in this research.

Discussion

Concept of Loss of Domain

Hernia defects are not all the same. They differ in their anatomic complexity but also in their associated co-morbidities and surgical history. Recently, Slater et al defined the concept of “complex hernia” by introducing four criteria: 1. defect size and location, 2. patient history and risk factors, 3. contamination and soft tissue condition, and 4. clinical scenario (5). The size of the defect is the outmost variable in hernia repair being an important risk factor for 30-day readmission due to severe local and systemic complications and recurrence.

The same group included IH with loss of abdominal domain (LOD) as being a complex hernia but without clearly specifying the defining criteria. LOD is a term used commonly in the literature to describe the distribution of abdominal content between the hernia and residual abdominopelvic cavity. Its repair is fraught by severe complications and even death (6). However, the definition has only prognostic value for failure or success prediction of the repair. The utility of LOD as a morphological predictor of peri- and postopera-

tive outcomes is limited.

Recently, an International Delphi Consensus of Expert Surgeons has developed a standardized definition of LOD; this is to be used for comparable pre-operative assessment and trial comparison. According to this consensus, LOD is a ventral hernia large enough such that simple reduction in its contents and primary fascial closure cannot be achieved without additional reconstructive techniques, without significant risk of complications due to raised intra-abdominal pressure (7). Regarding the volumetric method, the Consensus Group decided that the Sabbagh formula should be used to determine the index of LOD. This formula is the ratio, expressed as percentage, between incisional hernia volume (IHV), and the sum of the abdominal cavity volume (ACV), and IHV (8). All these volumes can be easily determined on a native abdominopelvic CT scan, using Tanaka method (9). Unfortunately, no consensus was reached in relation to the cutoff point the Group leaving the decision to the surgeon's choice. A value larger than 20% represents, in our opinion a minimum cutoff to consider an incisional hernia as being with LOD (10).

Evolution to a functional dynamic abdominal wall reconstruction (AWR) rather than simply patching a hole put these frail patients, with multiple co-morbidities and LOD to increased risk for developing intra-abdominal hypertension (IAH) or abdominal compartment syndrome (ACS). Efforts to reconstruct this failed abdominal wall in association with the reduction of herniated viscera within an unyielding stiff abdominal wall, without evaluation of the physiology of the abdominal compartment raises the specter of ACS (11,12).

Anatomy, Physiology, and Physiopathology of Loss of Domain

The abdominal wall is considered as a semi rigid cylinder that contains intra-abdominal viscera. It is delineated anteriorly by the rectus abdominis muscles enclosed in its sheaths and by the linea alba; laterally by the trilaminar complex composed of external,

internal oblique, and transversus abdominis muscles; posteriorly, the abdominal wall is limited by the lumbar vertebrae and erector spinal muscles (13). Due to this structure, it is flexible in its antero-lateral dimension and has potential cephalad distensibility (10).

The linea alba is the central tendon that fixes rectus abdominis muscles through its sheets, external oblique, internal oblique and transversus muscles through their large aponeuroses and ensures their coupling activity to stabilize torso, to allow coordinated movements (flexion of the abdomen, rotation and lateral flexion of the spine) and weight shifts. Individually, lateral abdominal muscles have different vectors of movement according to the direction of their fibers, but, when synergistic movements are employed, the overall direction of pull is to distract from the midline (13).

The top of the cylinder is the diaphragm and the bottom the pelvic floor; when they simultaneously contract, increase intra-abdominal pressure, and contribute to expiration, micturition, defecation, and parturition.

The natural history of IH is a gradual increase in size according to Laplace's law (simply stated the Law of Laplace says that the tension in the walls of a container is dependent on both the pressure of the container and its radius). As IH enlarges, complications occur and these become part of its natural history.

When an IH develops the structural and functional integrity of this cylinder is broken. The main problem of these patients is the absence of the anatomical and functional linea alba which leads to a combination of muscular disturbances, chronic respiratory and gastrointestinal pathology, and psychosocial issues.

In the absence of the linea alba, disinserted lateral abdominal muscles, are no longer mechanically coupled, lose their function, and become shortened. Because of the absence of activity and purpose, the muscle fiber loses its contractile ability and becomes shorter (2). A defect as large as $\frac{1}{4}$ of the abdominal circumference leads to retraction of the composite layer of the abdominal wall (internal oblique muscle and transversus abdominis muscle) by

20% on each side (14). The internal oblique muscle significantly reduces its elasticity and extensibility by 27%; stiffness is increased nearly 60% and tensile strength is increased too (15). The absence of strain results in decreased cell proliferation and modification of orientation angle of the fibroblasts. The lack of activity of the anterolateral abdominal group of muscles is a major hindrance to the back muscles that are not counterbalanced by the abdomen. Therefore, the spine is strained into a dorsal kyphotic accentuation and postural reflex contraction of the vertebral musculature. The rectus abdominis muscles and erector spinae muscles maintain torso stability also. Due to the disruption of the linea alba, rectus muscles became dysfunctional, and the columns are uncoupled which increases the pressure on the lumbar column. Back pain becomes a major symptom for which no statistics on prevalence are supplied in the literature (16,17). Upper and lower activities of the torso are also affected: decreased stabilization during physical activity, decreased coordination of movements, and inability to weight shifts. These modifications are reversible after abdominal wall reconstruction as stated by Dubay et al (14).

In patients with LOD, chronic respiratory insufficiency is a major feature. The altered respiratory function is a summation of pathological factors related to extreme obesity, smoking and cardiovascular comorbidities connected to factors induced by the loss of domain: loss of the contribution of the abdominal muscles, decreased IAP and diaphragmatic impairment. Secondary dorsal kyphosis is another contributing factor for respiratory disturbances. In 1973, Rives emphasized the therapeutic problems and respiratory implications of large abdominal IH introducing the term "thoracic-abdominal compartment" to describe the link between the chest and the abdomen (18). These complex alterations were named "volet abdominal" or "abdominal shutter". This leads to a four phases "paradoxical respiration" (18). Briefly, abdominal wall moves in and out during both inspiration and expiration being unable (together with the diaphragm) to contract

against the viscera. During inspiration, the bowels are forced out. The result is a major chronic respiratory insufficiency through reduced respiratory compliance (both pulmonary and thoraco-abdominal), increased resistance of the airways, decreased functional residual capacity, and decreased oxygenation. The entire mechanical work of breathing is altered. In obese patients, the presence of LOD can mask all these disturbances with an increased vital capacity and increased residual volume/total lung capacity ratio (18). These disorders underline the inefficiency of the diaphragm and abdominal muscles when their contraction acts on an open, extended, extra-abdominal cavity. The diaphragm does not contract against the abdominal viscera, which are no longer retained by the muscular abdominal wall. The decreased intra-abdominal pressure (IAP) alters the balance between intra-thoracic and IAP leading to the modifications of the diaphragm shapes which became flattened (19).

A decreased IAP induces disturbances in pressure within hollow viscera with chronic distension and chronic edema of the mesentery and visceral wall. Chronic traction of the outside viscera extends the mesentery, which thickens. The continued obstructed venous and lymphatic return add a new dimension to the increased global volume of the viscera. This leads to chronic bowel dilatation and the loss of the balance between the visceral and parietal tonus (19). The viscera chronically outside the abdomen suffer gravitational chronic stretching and elongation, which worsens the edema. Portal circulation is also affected and it is a contributing factor in venous mesenteric stasis. In association with visceral adhesions and incompetent abdominal wall, all the above-mentioned mechanisms lead to a poor bowel function, chronic micturition disorders, chronic abdominal pain, and discomfort.

The skin also suffers important changes. Usually, secondary to the pressure of the viscera, the covering skin becomes extremely thin due to an absence of the subcutaneous fat. Disorders of the subcutaneous circulation

induce local ischemia at the top of the bulge with skin ulcers. These ulcers are always infected, and microorganisms are always found at the edges of these ulcerations. The treatment is usually conservative with topical antibacterial agents rather than systemic antibiotics (20). Another dermatological problem is intertrigo, more frequently seen in diabetic patients. Unlike trophic ulcers, which cannot be eliminated, intertrigo is easy to treat and eradicated before surgery.

Physiopathology of Abdominal Wall Reconstruction

Closure of large defects is fraught with possible and severe complications. During repair, the sudden reintroduction of viscera into an unprepared abdominal wall cavity leads to sudden increase of the cavity volume and increase of the IAP. The abdominal cavity can accommodate modest increases in its volumes through reshaping and stretching; this explains why IAP does not exceed critical values with the most “modest” hernia repairs (15). When compensatory mechanisms are exceeded, IAP rises greatly and exponentially exposes the patient to intra-abdominal hypertension syndrome (IAHT) or, even worse, to abdominal compartment syndrome (ACS) with respiratory compromise, renal failure, mesenteric ischemia, pro-inflammatory status, and multi-system organ dysfunction. Obesity can exacerbate the increase of IAP (11).

Because AWR becomes more common, we shortly review the risks and implications of IAHT/ACS in the light of the potentially serious issues regarding IAP. Measuring the IAP before, during, and after AWR is often ignored and this represents a serious drawback because it is responsible for most respiratory shortcomings. Increased IAP elevates the diaphragm, reduces pulmonary and chest wall compliance, use of respiratory accessory muscles with increased effort of breathing for equal respiratory volumes, reduces airway clearance, and increases airway resistance. In association with the patient’s comorbid condition, this multifactorial

event trigger respiratory complications/failure.

In LOD patients, respiratory events have been reported in one of five subjects (21,22) and are associated with significantly increased surgical morbidity and mortality (18-fold greater death rate), prolonged hospital stay (four-fold greater), and additional cost burden. Incidence of postoperative pulmonary complications is unfortunately unclear given the lack of consensus on definitions and reporting in the literature (21). It is difficult to identify risk factors for postoperative respiratory morbidity, but it is important to do so in order to associate impact on resource mobilization and open the opportunity for the optimization of treatment strategies and interventions. Older age, male sex, congestive heart failure, lung disease, obesity, and sleep apnea are some of the risk factors independently associated with increased risk of respiratory failure (23). Fischer et al, recently identified that intraoperative blood transfusion, ASA score higher than 2, and fascial closure are surgical factors associated with respiratory morbidity (22). In a retrospective analysis, Mommers et al showed that hernia sac volume was highly associated in univariate and multivariate analysis with respiratory events ($p=0.045$; 95% CI: 1.008-1.910) (24). Oprea et al, recently demonstrated, in a retrospective study, that all patients developed IAHT in various degrees after transversus abdominis release abdominal wall reconstruction in patients with defects larger than 10 cm, and 24 of them (23.7%) had pulmonary involvement in their outcomes (25). The main factors involved in respiratory compromise were postoperative elevated IAP and hernia sac volume.

In patients with risk factors for IAHT, it is necessary to measure IAP with simultaneous evaluation of the respiratory function (26). No clear algorithm for monitoring these patients has yet been developed, but two main pressures values must be registered:

1. Peak inspiratory pressure – is the pressure required to push the air through the ventilator circuit and into the lung; it is measured at the end of the inspiration.
2. Plateau pressure – is the pressure

required to maintain the air space open after breath delivery. This value is not a function of flow resistance in the airway and is directly related to the recoil force of the lung and chest wall. Increased plateau pressure is closely related to a decreased compliance caused by abdominal hypertension. The difference between the values recorded at the opening of the abdominal wall and at the end of the anterior fascia closure is the delta plateau. If the value is larger or equal to 6 cm H₂O, there is a nine-fold risk to develop respiratory complications; the risk increases to 12-fold if the value is larger than 9 cm (19).

The increase of IAP during surgical repair and the early postoperative period is accompanied by deterioration of CO₂ elimination (increased P_aCO₂) followed by a decrease in arterial oxygenation (decreased oxygenation index - P_aO₂/F_iO₂); this suggests an impairment of the respiratory function after procedure.

One factor that can be involved in the outcomes of LOD patients is the abdominal compliance (C_{ab}) which reflects the ability of the abdomen to accommodate the reduction of large hernia volume. It plays a very important role in understanding the deleterious effects of misfit intra-abdominal volumes on IAP and organ dysfunction. Unfortunately, measurements of C_{ab} are difficult at the bedside. Some indirect measures are available in mechanically ventilated patients: the Δ IAP (= IAP at the end of inspiration minus the IAP at the end of expiration) and the abdominal pressure variation (APV= Δ IAP divided by mean IAP) are such parameters, and they are negatively correlated with C_{ab}, i.e., the higher Δ IAP or APV, the lower C_{ab} (10). Therefore, if we could identify patients with a low C_{ab}, we could anticipate and select the most appropriate surgical treatment in order to avoid possible complications related to IAHT/ACS (25,26).

Strategies to Avoid IAHT/ACS

LOD patients are not emergency cases in almost all instances but a challenge to

Table 1. Factors associated with decreased abdominal compliance

A. Related to anthropomorphy and demographics
• Male gender
• Old age (loss of elastic recoil)
• Obesity (weight, BMI)
• Android composition (sphere, apple shape)
• Increased visceral fat
• Waist-to-hip ratio > 1
• Short stature
B. Related to comorbidities and/or increased non-compressible IAV
• Fluid overload
• Bowels filled with fluid
• Stomach filled with fluid
• Tense ascites
• Hepatomegaly
• Splenomegaly
• Abdominal fluid collections, pseudocyst, abscess
• Diabetes
• COPD
C. Related to abdominal wall and diaphragm
• Muscle contractions (pain)
• Body builders (six-pack)
• Abdominal burn eschars (circular)
• Thoracic burn eschars (circular)
• Rectus sheath hematoma
• Multiple previous abdominal operations
• Mechanical ventilation (positive pressure)
• Fighting the ventilator
• Use of accessory muscles
• Use of positive end expiratory pressure (PEEP)
• COPD emphysema (diaphragm flattening)

restore the anatomic and functional integrity of the cylinder without severe complications. Therefore, the goal is to maximally optimize the patient with adequate preoperative preparation. Leaving aside systemic optimization (smoking cessation, albumin > 3.5 g/L, blood glucose level around 150 mg% and HbA1c less or equal with 6.5%, compensated

cardiovascular function) the semi-rigid container will require modifications: increasing capacitance (compliance), reducing the volume of the contents, physical enlargement of the container. For an optimal repair, all of these goals have to be fulfilled.

Reducing the volume of the contents – weight loss will decrease the volume of the abdominal viscera (central obesity) which is an important part contributing to IAHT. Although visceral content can be reduced assuming omentectomy, right hemicolectomy or enlarged small bowel resection. There are no large studies to confirm the benefits of such procedures and in general they are encumbered by serious risks and complications such as fistulas, mesh infections, etc.

Optimizing compliance – use preoperative injections of the abdominal wall with Botox 4 to 6 weeks before surgery.

Enlargement of the container – use preoperative progressive pneumoperitoneum alone or associated with Botox. The container can be enlarged using unilateral or bilateral anterior (Ramirez) or posterior (transversus abdominis muscle release – TAR) component separation techniques. In a recent study, TAR show an increase of the peritoneal volumes almost identical to the preoperative calculated value (11,015.82 ± 2,184.44 cm³ versus 12,171.8 ± 2079.07 cm³; (Student’s t test: P = 0.076; F test: P = 0.739) (10).

In a recent review, primary closure was achieved after PPP in 84% of the patients after PPP and in 100% in Botox patients (12). The recurrence rate ranged between 6 and 7.2%.

Table 2. Advantages of the PPP and BTX for optimization of the abdominal wall

Progressive preoperative pneumoperitoneum	Botox injections
1. Increasing of the ACV with 49 to 53% within 15 to 21 days of insufflation	1. lateral muscle relaxation – increase visceral reduction
2. Increasing of the abdominal wall muscle length up to 9 cm	2. reduce lateral physiological forces – decrease defect
3. Pneumatic adhesiolysis; reduce the amount of dissection and operative time	3. reduce tension at closure – decrease IAP
4. Improves diaphragmatic function	4. ensure suture line protection – low recurrence rate
5. Reduces the chronic edema of the mesentery	5. increase muscle length, decrease lateral m thickness
6. Unmasked additional defects	6. increase transversal length of the AW
7. Spontaneous reduction of the viscera	7. primary fascial closure in up to 85%
8. Fewer analgesic requirements	8. decrease pain

Lessons to Be Learned

1. LOD is a morbid condition with a poor quality of life for the patient.
2. Abdominal CT scan is mandatory for defining LOD and for assessing the nature of the contents, volume of the contents of the sac, the percentage of the contents in the sac, and the size of the defect.
3. It is necessary to know the anatomical and physiological changes in the abdominal wall and abdominal wall cavity, which develop during the evolution of a giant hernia.
4. Systemic optimization by a multidisciplinary team (pneumologist, cardiologist, anesthetist, nutritionist, bariatric surgeon) is essential for a good quality surgery and optimal results.
5. Abdominal optimization alone or in combination with PPP and/or BTX is the cornerstone in avoiding IAHT/ACS and severe respiratory complications.
6. Always use an abdominal wall reconstruction through a mesh augmented component separation technique, which increases intra-abdominal volume and restores domain through myofascial advancement and medialization of the rectus complex.
7. Monitoring of IAP, plateau pressure, and PEEP are easily quantifiable parameters for determining high-risk patients. If delta plateau values are higher than 6 cm H₂O, keep the patient intubated and ventilated for 24 hours in order to prevent respiratory failure induced by IAHT. Postoperative respiratory morbidity is a relatively understudied area in AWR and warrants significant attention as postoperative risks can be significant.
8. Open communication between surgical and anesthesia teams can improve patient care.

Author's Contribution

All authors equally contributed to literature search, drafting the manuscript, and revising the final form.

Conflict of Interest

The authors declare no conflicts of interests.

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