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Giant Omphalocele: what's the way to go?

Abstract

Giant omphalocele (GO) represents a challenge for paediatric surgeons. Management of GO has been discussed extensively over the past 50 years but still represents a topic of debate and up to date there is no general consensus. Hereby are summarized the numerous strategies, techniques, materials and experiences reported in the literature to treat such challenging cases.

Keywords: giant, omphalocele, exomphalos, hernia, prosthesis, closure, primary, staged, delayed

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Abbreviations: GO: giant omphalocele, VAC: vacuum assisted closure, ADM: acellular dermal matrices

Introduction

Omphalocele is a known congenital anomaly consisting with a periumbilical abdominal wall defect determining the herniation of viscera into a sac made up of peritoneum, Wharton's jelly and amnios. When the defect is larger than 5-6 cm with herniation of most of the liver and bowel into the sac, the condition is commonly referred to as giant omphalocele (GO). The latter represents a challenging situation to manage because of the disproportion between the volume of herniated viscera and the intra-abdominal capacity, that Gross.[1] suitably described as the abdominal viscera having lost its "right of domicile" in the peritoneal cavity. This makes very difficult to reduce all viscera and close the abdominal wall defect without risking an excessive intra-abdominal pressure.

Management of GO has been discussed extensively over the past 50 years but still represents a topic of debate. Hereby is presented a review of the literature to analyze what is currently proposed for the management of similar cases.

Incidence and associated anomalies and conditions

The incidence of omphalocele is 1 in 4000.[2] live births, but for GO is 1 in 10000.[3] Associated congenital malformations, mainly cardiac defects and karyotypic anomalies, are present in almost half of cases. The incidence of cardiac anomalies, including ventricular septal defects, atrial septal defects, coarctation of the aorta, tricuspid atresia, and ectopia cordis, is reported between 20-45%, with some of these conditions considered lethal (i.e. ectopia cordis) and other requiring hemodynamic support and complex cardiac surgery, thus having a high impact on overall survival. Furthermore, newborn with GO often suffer from pulmonary hypoplasia, resulting from the impaired ability of the child to achieve positive pressure during normal fetal breathing movements.[4,5]. This condition may determine-persistent pulmonary hypertension of the newborn and early respiratory distress, thus requiring intubation and ventilatory support at the time of delivery. Omphalocele can be part of complex syndromes such as OEIS (omphalocele, cloacal exstrophy, imperforte anus, and spinal anomalies), pentalogy of Cantrell (midline supraumbilical abdominal wall defects, deficiency of the anterior diaphragm, defects in the diaphragmatic pericardium, defects of the lower sternum, and congenital intracardiac defects) and Beckwith-Wiedemann syndrome (macroglossia, macrosomia, midline abdominal wall defects, ear creases or ear pits, and neonatal hypoglycemia). Chromosomal abnormalities, especially trisomy 13, trisomy 18 and trisomy 21, can occur in up to 48% of neonates with omphalocele. Compared to smaller omphaloceles, the incidence of chromosomal abnormalities in GO is less common.[2,6]. Global morbidity in GO becomes much higher in presence these associated anomalies, making even more difficult the management of this already challenging condition. Mortality in GO, ranging between 10-34%, has been reported not only in developing countries,[7,8] but also in highly resourced settings,[6,9,10] due to severe respiratory.[5] and hemodinamic failure and sepsis, mainly related to the associated anomalies.

Overview of surgical management

The possible management of GO is classically divided into three main strategies: primary closure, staged closure and delayed closure. Primary closure happens shortly after birth, with or without the use of a prosthetic patch, mobilizing undermined skin flaps. The benefit is the immediate closure of the abdominal defect, thus reducing the risk of sepsis. The disadvantage with primary closure it's the higher risk of producing an excessive intra-abdominal pressure with consequent kinking or compression of the inferior vena cava, liver, and hepatic veins, determining hemodynamic and respiratory failure that can be eventually fatal. Another risk is overstretching of the skin, especially if a patch has been used to fill the gap of muscular sheath, with consequent possible poor skin quality and even necrosis. Furthermore sometimes the interposed prosthetic patch needs to be removed (i.e. in case of mislocation, infection, etc.). The mean recurrence rate of hernia after primary closure is reported around 58%.[11]

Staged closure, happens through planned multiple surgical procedures, most of the time using extracorporeal material, either temporarily or permanently. The main advantage is the gradual reduction of the hernia content with controlled increase of intra-abdominal volume without excessive pressure. Disadvantages are the need of multiple anaesthesias and surgical procedures, prolonged muscular paralysis and mechanical ventilation, the high risk of local and systemic infections, plus the high cost of multiple admissions and often the use of more than one prosthetic material. The mean recurrence rate of hernia is reported around 18%.[11]

Delayed closure relies on the progressive escharification and spontaneous epithelization occuring to the sac usually within 2-3 months, but sometimes up to 6months,[12] until when the surgical repair is deferred. The advantage is the complete avoidance of increasing the intra-abdominal pressure and need for mechanical ventilation,

and the possibility to feed the child immediately after birth.[13] Delaying a delicate surgical and anaesthetic procedure in a newborn baby is particularly advantageous in case of prematurity, significant pulmonary hypoplasia, cardiac anomalies, and chromosomal abnormalities.[6,14] Furthermore it is possible to observe with the time a partial spontaneous reduction of the hernia content and relative increase of the abdominal capacity which would make the delayed surgical procedure easier. Disadvantages are the prolonged hospital stay, the risk of topical and systemic infections, sac rupture and bowel obstruction.[6,8] Bowel motility disorders, up to bowel occlusion and perforation, have been reported especially in the experience of developing countries where the initial conservative treatment and delayed closure of omphalocele is often the only feasible way to go.[7,8] The surgical repair may require the use of a prosthetic patch. Timing of definitive surgery in delayed closure of GO depends on surgeons' choice and procedures have been accomplished anytime from as early as the epithelisation is complete up to preschool age. van Eijck et al.[15] recommend to operate between 4 and 6 months because of the motor development of the child and optimal ratio between omphalocele and abdominal cavity in that period. Mean reported recurrence rate is 9%.[11]

Primary closure

Initial management of GO by elastic bandaging[16] or external compression[17] or sequential ligation[18] of the sac and its content have been reported as useful tools to achieve early reduction of the hernia for primary closure. In 2003 Hendrickson et al.[19] reported the management of GO in a premature low-birth-weight neonate utilizing a bedside sequential clamping technique of the sac without prosthesis. In 2006 Morabito et al.[10] reported the functional and cosmetic effectiveness of GO primary closure by a traction-compression technique. This method requires the sac to be intact or repairable and the patient to be paralyzed and ventilated, thus the abdominal wall can be stretched by vertical cord traction against the baby's weight, and, once the liver and bowel have detached from the sac and entered the abdominal space, the cord traction is replaced by downward compression with a circumferential elastic body binder, and a series of gauze swabs are placed sequentially beneath the binder to maintain reduction, until the defect is surgically closed (after 3-5days) through a midline scar by dissection of the sac and a layered closure, apposing the fascia and preserving the umbilicus. In 2005 the group from Kings College Hospital, London.[20] compared their infants with GO who underwent primary surgical closure with those whose primary closure was not feasible and who needed a staged closure with a silo. The group with primary closure required shorter periods of ventilation, shorter hospital stay, and shorter periods to achieve full enteral feeds compared to the staged closure group, thus they stated that an aggressive surgical approach in infants with GO is a safe and effective.

Staged closure

Historical management, introduction and modern use of the silo: In 1940 Ladd and Gross,[21] inspired by the skin flap mobilization originally described in 1887 by Olshasen, described a first stage operation consisting in excising the sac of the omphalocele and mobilizing skin flaps from the border of the defect to be advanced medially and sutured to each other to cover the intestine. Second stage, consisting with repair of the residual abdominal hernia would be carried out after 6-12 months, when the abdominal cavity is big enough to allocate all the viscera without over tension and to be closed by layers, including muscles and fasciae.[22] Modifying his original first stage technique, in 1948 Gross.[1] reported three cases of GO treated by mobilization of undermined skin flaps from the border of the sac to be advanced and closed in the midline over an intact sac, adequately cleansed and sterilized by iodine-alcohol solution and left underneath. Schuster[23] in 1967 introduced the use of a Prolene mesh to be applied over the intact amniotic membrane and sewn along the medial edge of the rectus muscle in order to achieve sequential reduction of the sac content and amnion inversion. Two years later Allen and Wrenn[24] reported the similar use of a Silastic silo to be sutured to the fascial edges in case of gastroschisis or ruptured omphalocele, and instituted the use of local antibiotics into a bulky dressing around the exposed prosthesis to reduce the septic risk. Complete reduction is typically achieved over a period of 7 to 10 days.[4]. In 1991 De Lorimier et al.[25] described six cases of giant omphalocele with an intact sac progressively inverted into the abdominal cavity by using a Silastic silo sutured the to the skin-amnion junction. Second stage consisted with incision at the skin-amnion junction to expose the linea alba which was approximated, while leaving the amnion intact and infolding it into the abdominal cavity. The Silastic sheet can be sutured to the skin even under local anaesthesia, as reported by Yokomori et al.[26] The team from Great Ormond Street London recently reported positive results by a staged procedure using a silo of Prolene mesh widely sewn to the fascia in two rows, without opening the amniotic sac which is eventually inverted in the abdominal cavity for sequential reduction.[27]

Techniques-to achieve secondary skin closure: The group from Bambino Gesu Children's Hospital, Rome, reported in 2003[28] and 2004[29] the feasibility and good outcome of reconstruction of the abdominal wall in GO within as early as 10 days of life by initial use of Shuster's silo followed (as soon as the reduction of all viscera has been accomplished) by closure of the aponeurotic-muscle plane, either through direct approximation of its borders or by interposition of a Prolene mesh, and by the use of two bipedicled skin flaps elevated from each side of the abdominal defect and then approximated and sutured on the midline, thus achieving a tension-free closure of all layers of the abdominal wall and finally covering the donor sites of the skin flaps with split-thickness skin grafts harvested from the thigh bilaterally. Staged closure combining the use of Silastic silo for initial reduction, followed by abdominal fascial gap closure with Vicryl mesh, followed by split-thickness skin graft or skin flap coverage over the granulation tissues grown over the mesh, has been reported by Bawazir et al.[4] in 2003. Dynamic wound closure systems by external devices generating resultant force vectors that enhance the "mechanical creep", a biomechanical property of skin that allows it to gradually stretch beyond the limits of its inherent extensibility, have been reported to significantly decrease days to surgical abdominal closure and reduce the need for skin grafting.[30] In 2006 Kilbride et al.[31] described the use of vacuum-assisted closure (VAC) devices as a safe and effective alternative way in treating 3 cases of GO, where initial treatment by staged silo reduction or prosthetic patch closure failed or gave complications. After removal of the prostheses, the VAC device, consisting of a sponge covered with impermeable transparent dressing and attached to a low negative pressure system, was applied directly to the bowel and liver bed underneath the defect, assisting to rapid shrinkage and reduction of the viscera (within 22-45 days), cleansing of the wound, excellent granulation of the bed (for skin flaps or free grafts), maintenance of a sterile environment, and ease of use (changes of VAC dressing every 3 to 5 days possible at the bedside under local sedation). Similar results have been reported recently by Binet et al.[32] who recommended not to close the wound at all costs in those cases where skin closure can only be obtained by overstretching the skin and thus risking dehiscence, but rather to use the VAC device as an initial protective cover, even over a prosthetic patch.

Tissue expanders: The use of tissue expanders, is a way to achieve a controlled gradual increase of the abdominal cavity to later allocate the viscera, usually within 1 month. They can be inserted either by open or mini-invasive technique.[33] Bax et al.[34] reported in 1993 the first case of GO treated by insertion of an intra-abdominal tissue expander. Other cases were reported by Foglia et al.[35] in 2006 as well as by Martin et al.[33] in 2009, where the use of intraperitoneal tissue expanders has been combined with use of temporary or permanent implanted prosthesis, and resulted successful even to treat cases with huge viscero-abdominal disproportion. Computed tomography allows preventive calculation of the intra-abdominal volume growth required and how much the tissue expander should be inflated. Furthermore tissue expanders allow to precisely control the amount of intra-abdominal expansion and pressure, being possible to deflate them should any sign of excessive abdominal pressure appear. A technique of placing tissue expanders in the subcutaneous space[16] or in the abdominal wall, between the internal oblique and transverse abdominal muscles,[36] instead of the intraperitoneal cavity has been also reported and declared to be safe, despite the theoretical risk of damaging the neurovascular bundle of the abdominal wall.

Delayed closure

Delayed closure was first reported by Ahlfeld[37] in 1899 and recommended since 1963 by Grob[38] and Soave.[39] According to Bax et al.[34] even a fresh tear in the omphalocele does not preclude conservative treatment, because such a tear can easily be closed with a running suture in the neonatal intensive care unit without anesthesia.

Escharotic agents: The escharotic process is spontaneous, thus protecting the sac with sterile dry or paraffine oiled gauzes.[34] and bandages would be enough, but it's normal practice to apply topical substances in order to guarantee an antiseptic environment while enhancing desiccation. Many of these topical agents have been abandoned because of their toxicity and side effects (alcohol,[37] mercurochrome,[8] silver nitrate), while other are still used (povidone-iodine,[8,12] silver sulphadiazine,[6,13] eosin.[7]) despite issues concerning their safety are still debated. Whitehouse et al.[12] recently reported that the clinical relevance of thyroid function abnormalities following topic use of povidone-iodine is minimal and transient but they still recommended weekly monitoring of thyroid function to prevent the rare but significant sequelae of undiagnosed hypothyroidism. Kouame et al.[7] reported their experience on local application of dissodic 2% aqueous eosin as conservative treatment on GO, stating that it is a simple, effective and practical method, which can easily be taught to the mothers to reduce the hospital stay, especially in a setting of developing countries with limited resource. Similarly Ein and Langer[6] reported the treatment with silver sulphadiazine cream to be effective, inexpensive and easy to be continued at home by the parents when the accompanying medical problems are stabilized enough to allow the patient's discharge. As stated by Lewis et al.[40] the risks of silver toxicity include seizures, peripheral neuropathy, ocular pathology, nephrotic syndrome, raised liver enzymes, leukopenia, and argyria. They described two babies with GO being treated with topical silver suphadiazine, who had disconcerting markedly elevated silver levels during the treatment (200 times that seen in the normal adult population and more than 3 times the levels seen in silver workers) that dramatically fell following cessation.-In 2010 Almond et al.[3] described the use of a silver impregnated hydrofiber dressing for conservative treatment of GO. This dressing, differently from silver suphadiazine, does not dry out nor form a black hardened necrotic eschcar on sac, but rather guarantees a moist environment which favours autolytic processes and assists in the debridement of the necrotic tissue and exposure of newly formed tissue. Results of a review from a paediatric burns unit reported by Paddock et al.[41] in 2007 clearly show that, despite the apparent expensiveness, the use of this silver impregnated hydrofiber dressing was able-to reduce the global costs because of less dressing changes (change of dressing every 3 to 7 days), less hospital readmissions, decreased length of stay, and-decreased infection rate. Malhotra[42] in 2009 reported one case of GO in a term baby managed conservatively with ACTICOAT (Smith & Nephew Medical Ltd, Hull, England). Introduced in the late 1990s, ACTICOAT is a special nanocrystalline silver dressing that releases 30 times less silver cations than silver sulfadiazine but sustained and for a longer period of time, up to 7 days. ACTICOAT has been extensively used in the management of burns. Low levels of serum silver and no haematological nor biochemical indicators of toxicity associated with the silver absorption have been reported in 2007 in a prospective study from Vlachou et al.[43] and a more recent systematic review from Khundkar et al.[44] showed that ACTICOAT has better antimicrobial activity, fewer adverse effects and reduces healing times compared to other available silver dressing. The use of ACTICOAT has been reported feasible and effective even in the management of neonatal burns, with very low serum silver levels and no systemic side effects.[45]

Plastic surgical techniques for delayed abdominal wall restoration: Many strategies have been employed in an effort to provide an effective restoration of the abdominal wall integrity that can withstand the dynamic stresses placed on it. In 2004 Pereira et al.[22] reported 11 cases of delayed closure of GO using the surgical technique originally described by Da Silva[46] in 1971 for the treatment of abdominal hernia in adults. This technique uses flaps of rectus sheath and the fibroperitoneal tissue of the hernial sac itself, creating three overlapping layers that approximate the medial edges of the rectus muscles to the midline, with the advantage of reducing the suture line tension by its distribution between the three layers, without necessity of prosthetic materials. In 2008 van Eijck et al.[15] presented positive results from a series of 10 patients operated with the component separation technique, a surgical method based on enlargement of the abdominal wall surface by translation of muscular layers without compromising their innervation and blood supply. According to this technique, introduced in 1990 by Ramirez et al.[47] and used for abdominal wall reconstruction in adult patients with large midline hernias that cannot be closed primarily,[48] the aponeurosis of the external oblique muscle is incised over its full length, approximately 1 cm from the lateral border of the rectus abdominis and the external oblique is separated from the internal oblique in the avascular plane between both muscles up to the midaxillary line. In this way, the external oblique muscle is retracted laterally while the rectus muscle can be shifted medially 5 cm at each side and the abdominal wall can be closed in the midline, usually without the interposition of any prosthesis, with excellent cosmetic results and no recurrence of hernia reported.

Prosthetic patches: Despite the obvious advantages of using the patient's own tissues, they are often inadequate to provide complete restoration of the abdominal wall. Here it comes the need for a prosthetic patch.

Synthetic meshes: Synthetic non reabsorbable materials as polypropylene (Marlex or Prolene), polytetrafluroethylene (Gore-Tex), polyester (Mersilene), although beneficial in many cases, can be associated with high rates of infection, delayed wound healing, fistula formation, and seroma.[49,50] Furthermore these meshes remain permanent foreign materials for the body, possibly causing the

development of chronic inflammation and fibrosis and, consequently, complications such as chronic pain and abdominal wall stiffness.[51] Bawazir et al.[4] in 2003 recommended the use of absorbable synthetic meshes as polyglycan (Vicryl) for staged coverage in the treatment of GO, followed by split-thickness skin graft or skin flap coverage of the skin residual defect after adequate granulation. Unfortunately these absorbable non-biological meshes remain intact for only three weeks, which may be an insufficient time to create the adequate tissue strength from cellular remodelling.[52] Furthermore, also synthetic-absorbable prosthetic materials for hernia repair have been associated with complications including early surgical site infection, skin erosion, seroma formation, and later, bowel obstruction or fistula formation.[53] Synthetic meshes are particularly susceptible to bacterial contamination and chronic infection, because bacteria adhere avidly to the synthetic polymers and lay down a biofilm, which protects them from host immunological defences and from antibiotics, contributing to bacterial survival.[53] Infection frequently requires removal of synthetic prosthesis.[53,54]

Prosthetic biologic meshes: In 2003 acellular dermal matrices (ADM) derived from human (allograft) or animal (xenograft: porcine or bovine) tissues were introduced as biologic meshes for abdominal reconstruction, offering many theoretical advantages over synthetic materials, largely resulting from their enhanced biocompatibility, as an increased capacity for integration with surrounding tissues by native tissue in growth and revascularization, while demonstrating resistance to infection, extrusion, erosion, and adhesion formation,[55] so that they can be placed directly on exposed viscera and used in contaminated fields. Because of these benefit that separates biologic meshes from synthetic ones, ADM have been extensively used in adults for wall reconstruction after tumor resection, ventral and incisional hernias, acute trauma, intra-abdominal sepsis, and necrotizing fasciitis, but recently they have been applied also in paediatric surgery for the reconstitution of the anterior abdominal wall defects, like GO, and repair of primary and recurrent hernias.[49] The use of ADM in paediatric surgery is attractive, not only because of the lower rate of complications, but because of the absorbable nature of the patch as well as the incorporation of host tissues into the patch which will grow with the child.[56] Downsides include higher cost, and in theory, potential disease transmission.[53] Collagen-rich tissues (skin, pericardium, intestinal submucosa) are harvested and treated to remove cellular elements, leaving the collagen and elastin scaffold intact. An additional chemical manipulation for some prostheses involves collagen cross-linking which has the effect to retard the degradation of the collagen by blocking collagenase-binding sites, so that the prosthesis remains structurally intact for a longer period of time compared with non-cross-linked materials, but could also prevent sufficient ingrowth of host tissue and, consequently, adequate tissue remodelling.[53,57] Bacterial collagenases are responsible for the breakdown and resorption of implanted collagen materials. Experimental studies have demonstrated that collagen cross-linking with glutaraldehyde imparted resistance against the activity of collagenase,[58] thus cross-linked biologic prostheses should therefore be relatively resistant to bacterial degradation, and therefore, safe to use in contaminated or infected hernia repair.[53] Biologic prostheses may be replaced by native tissues over time and, serve only as a temporary scaffold for host cells to grow into. The clinical utility of biodegradable materials depends on the balance between the rate of degradation and the rate of native tissue ingrowth. In fact if a biologic prosthesis is absorbed before adequate collagen differentiation, deposition and neovascularization, the overall quality and strength of the newly formed tissue will likely be insufficient for abdominal wall repair.[53]

Most published experimental studies deal with three biologic materials currently employed in the clinical setting: AlloDerm (LifeCell Corporation, Branchburg, NJ), a dermal matrix obtained from human cadaveric split thickness skin; Surgisis SIS (Cook Biotech, West Lafayette, IN), an extracellular matrix acquired from the submucosal layer of pig jejunum; Permacol (Tissue Science Laboratories, Andover, MA), a porcine derived cross-linked dermal collagen. Other bio-prosthesis, less commonly reported in management of abdominal wall defects are Peri-Guard and Veritas (Synovis Surgical Innovations, St. Paul, MN), which are respectively a cross-linked and a non-cross-linked mesh derived from bovine pericardium,[53] Strattice (LifeCell Corporation, Branchburg, NJ), which is a non-cross-linked porcine-derived acellular dermal matrix[52] and Tutoplast (Tutoplast Pfrimmer, Lyofil-Pfrimmer, Erlangen, Germany), acetone dried dura patch of human origin.[59] A recent systematic review by Janis et al.[49] including 40 articles reporting the use of ADM in abdominal wall reconstruction in adults, revealed absence of high-quality evidence, but, overall, the results would indicate that there are concerns regarding the high incidence of recurrent hernias and abdominal wall laxity (bulging) following ADM repairs, especially if used as a bridging repair compared with reinforced primary fascial closure repairs, and when human ADM is used. Other possible complications of ADM, revealed by another recent review from Patel and Bhanot[54] are fluid collections (seroma), and more rarely abdominal skin loss and infection, all likely related to the extent of undermining of the skin flaps with consequent impairment of vascularization. Human ADM (e.g. AlloDerm) was introduced first among the biologic products and gained widespread use quickly, that's why the most commonly used ADM in those reviews was human. Successful early outcomes based on tissue incorporation, low infection rates, and reduced fistula formation made human ADM option desirable, but late outcomes were less than desirable, with a high incidence of abdominal wall eventration and recurrence reported to be as high as 100 percent.[60] According to Patel and Bhanot[54] recurrence and laxity are often caused by fascial repair dehiscence or suture failure at the mesh interface and can be reduced by technical tips, as using an appropriate amount of mesh/fascia overlap and placing the biologic mesh under near-maximal tension to prevent early bulging in bridged fascial repair. An animal study comparing two cross-linked (Peri-Guard and Permacol) versus two non-cross-linked biologic mesh (Veritas and AlloDerm), showed ingrowth and neovascularisation were similar at 3 months in each of the four biologic prostheses with all four bio-prosthesis tested becoming firmly incorporated into the abdominal wall. Permacol resulted the biomaterial providing the strongest and more durable repair. In fact hand tensile strength after 6 months was significantly reduced for the non-cross-linked prostheses (Veritas and AlloDerm) compared to the cross-linked prostheses (Peri-Guard and Permacol), with Peri-Guard resulting as strong as Permacol but prone to infection and to skin ulceration. Stretching, bulging, and translucency were routine with AlloDerm, possibly related to the high elastin content of human cadaveric skin. Mean adhesion coverage area was similar, ranging between 25-31%.[53] Confirmation of those findings were reported in a rat incisional hernia model by Broderick et al.[61] were AlloDerm implants exhibited the most rapid and extensive cellular infiltration, compared to Permacol, despite at 6 months both the meshes had evidence of cell penetration throughout the implants. However AlloDerm implants thinned significantly by 6 months, in contrast with Permacol.[61] The recent experience with Strattice showed similar properties to AlloDerm. Strattice exhibited high cellular infiltration and neovascularization demonstrating to be particularly useful in the repair of abdominal wall hernias in potentially contaminated fields. Furthermore, this emerging non-

cross-linked porcine dermis derived xenograft is reported to have significantly reduced levels of the 1,3-a-galactose epitope, believed to play a major role in the xenogeneic rejection response. Strattice has lower tensile strength in comparison with cross-linked mesh (like Permacol) and its hernia recurrence is reported to be over 20%.[52-54] In an animal study Surgisis mesh showed increased neovascularization over AlloDerm.[62] A prospective study comparing the efficacy and the complications associated with the use Surgisis and Alloderm in ventral hernia repair on adult human patients showed that seroma formation and post-operative pain was a major problem with the non-perforated Surgisis mesh repair, but, on the other hand, post-operative diastasis and hernia recurrence were a major problem with the Alloderm.[63] Most of the published data on biologic mesh used to repair abdominal hernias in humans exist in retrospective reviews and small case series. In 2012 an extensive literature review conducted by Smart et al.[52] on 45 publications suggested that there is only sufficient data to draw conclusion on three meshes: Alloderm, Surgisis and Permacol. According to this data AlloDerm has the highest recurrence rates (up to 100%) while Surgisis performs reasonably in clean or clean-contaminated fields (recurrence rate up to 39% in infected fields) and Permacol has the lowest failure rate (0-15%) and the longest time to failure, particularly in contaminated fields. In the same period data from another systematic review on 29 published series conducted by Beale et al.[64] showed that mean reported recurrence rates for the devices Alloderm, Permacol, and Surgisis were 21%, 11%, and 8%, respectively, and similarly the mean rates of surgical site occurrence, as hematoma, seroma, wound infection, dehiscence, or need for graft removal for each device were respectively 31%, 25%, and 40%. Despite most of the published series, as well as the highest cumulative number of patients treated with biologic mesh products for complex abdominal hernia repair, refers to AlloDerm, this review objectively supports the current trend that the use of these devices has moved away from allograft toward xenograft because of the larger and thicker available sizes and the favourable viscoelastic properties in these products.[64] and the beneficial role of xenograft in reducing recurrence rates and surgical site complications in open abdominal hernia repair. These results are concordant with findings from high quality animal studies,[53,61,62,65,66] but, given the lack randomized controlled trials studies, they need to be better confirmed. In the recent 10 years case reports of neonates with abdominal wall defects treated with AlloDerm.[67-69] and a few case series of similar patients treated with Surgisis[56,70-72] have been published. These meshes allowed skin coverage by direct mobilization of skin flaps over them or by spontaneous granulation and epithelization over the mesh, possibly enhanced by the use of VAC dressing[7,0] or by skin graft. Enthusiastic results have been reported especially in a setting of contamination, observing resolution of cases of infections with antibiotic therapy only, without requiring patch removal.[56,72] Reported recurrence rates ranged from 8 to 38%.[56,72] Spontaneously resolving seroma was reported with Surgisis.[72] Problematic abdominal wall laxity has been reported, especially with AlloDerm, requiring abdominoplasty at older age,[56,68] though spontaneous resolution of laxity over time has been reported too.[69,72]

Experimental synthetic mesh: Synthetic scaffolds that are less expensive than biologic meshes were recently developed but their application is still experimental. These materials, as well as biologic meshes, are gradually resorbed by the body, while maintaining adequate mechanical strength that allows formation of sufficiently strong host tissue. In a recent rabbit study, a synthetic absorbable mesh called GORE BIO-A Tissue Reinforcement, was associated with optimal tissue remodelling with complete mesh resorption, tensile strength similar to native abdominal wall tissue, moderate intra-abdominal adhesion formation, and no inflammation.[73]

Liver resection

In a series of 3 cases, Pelizzo et al.[74] described the abnormal macroscopic appearance of the herniated liver in GO as globular, oedematous and without difference in size between the left and right lobes, to support its extra-abdominal development. Partial hepatectomy and total splenectomy have been reported in the past literature as radical procedures for primary closure of GO.[75,76] Such procedures are no longer indicated since staged or delayed techniques are available. Another case of combined right hepatectomy and upper hemi-splenectomy has been reported more recently for a delayed GO correction.[77] If required, partial splenectomy should be preferred in children to alleviate the risk of overwhelming infections. Liver lobectomy can be performed with no major risks to healthy patients and is well tolerated when the liver is normal, as now demonstrated on living related donors for liver transplantation.[78]

Conclusion

Having reviewed all the different philosophies to approach the problem of GO and having seen the numerous different techniques, experiences, devices and high performing prosthetic materials usable to surgically treat those complex and challenging cases it has to be finally mentioned the result from a questionnaire published by van Eijck et al.[11] in 2011 which confirmed that there is still no consensus about what the best management of GO should be and revealed that 42% of the interviewed authors modified their management over the last 40years. Because of the relative low incidence of GO, randomized multicenter trials would be recommended to define management guidelines.

In absence of a consensus on the best management for newborns with GO, the author would suggest to favour a conservative treatment, using an escharotic agent that is safe, easy to use and that possibly allows delayed change of dressing (i.e. ACTICOAT.[42-45]), while allowing the baby to be fed soon after birth, whenever possible, with little stress in this extremely delicate period of life, not only for those children with prematurity or associated anomalies. During this time the baby can undergo all the necessary work-up to identify associated anomalies. The baby can be discharged home whenever stable and all screenings have been done and can come back to the hospital for weekly change of dressing (when ACTICOAT 7 is used), without systemic antibiotic prophylaxis. Timing for definitive repair should be guided by the patient's general conditions and by the naturally occurring relative reduction in size of the hernia compared to the growing abdominal cavity: whenever the abdominal capacity results big enough to attempt to allocate the herniated viscera, with or without complete escharification of the sac, the sac can be excised, hernia content reduced and abdomen closed by layered closure apposing the fascia with or without the use of a prosthetic patch. If a patch is required the suggested mesh to use is Permacol, the biologic mesh which confers the strongest and more durable repair with the lowest failure rate, performing well even in contaminated fields, while maintaining an adequate host tissue in-growth, collagen deposition, and neovascularisation.[51,53,61,62,64-66] In case of big fascial defect, the wall components separation technique.[15,47,48] can be used in order to reduce the size of the required prosthetic patch. If skin is insufficient to close the defect over the patch, the bipedicled sliding flaps technique described by the Bambino Gesù team.[28,29] can be adopted or closure can be achieved by aid of VAC followed by free split-thickness skin grafts over the new formed-granulation tissue. In case of persistent

insufficient intra-abdominal space, abdominal capacity growth can be boosted by intraperitoneal tissue expanders.[33–35] A flowchart with the author's suggested management for GO is reported (Figure 1).

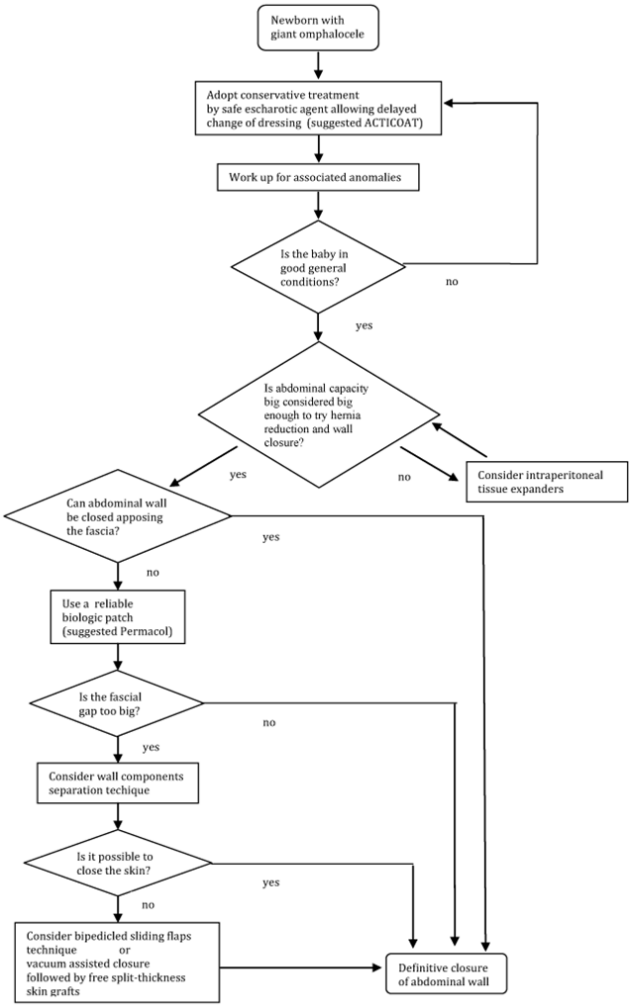

Figure 1 Author's suggested management for giant omphalocele.

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Conflicts of interest

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