Hernioplasty of induced diaphragmatic hernia in dogs via a comparative study between implantation of polypropylene mesh and latissmus dorsi muscle

O. H. Al-Hyani, A. Kh. Al- Jobory, O. A. Bader and E. R. Al Kennany
College of Veterinary Medicine\ University of Mosul

Abstract

The research was designed to know the difference between non absorbable synthetic material (polypropylene mesh) and natural muscle auto graft (latissmus dorsi muscle) to repair diaphragmatic hernia in dogs. Twelve adult dogs from both sexes was used. The animals was divided into two groups, each group consists of six animals. In all animals, diaphragmatic defect was induced by removal a circular piece about 5 cm in diameter from muscular part of diaphragmatic tissue. The defect was left without any surgical intervention for about 3 weeks until occurrence the ideal feature of diaphragmatic hernia though by depending on the clinical and radiological signs for each animal. In first one, the diaphragmatic hernia was closed by using polypropylene mesh while in second group the hernia was treated by application piece of latissmus dorsi muscle. The evaluation of each graft in all animals was established by study the gross and histopathological changes at 7 and 21 postoperative days. The study was showed a differences between each graft where the repair of hernia in first group with polypropylene mesh lead to adhesion formation less than in second group, furthermore the infiltration of mononuclear inflammatory cells was less than second group, also the interposed of collagen fibers extension between the diaphragmatic tissue and polypropylene mesh was rapidly develops as compared with muscles grafting additionally the grafting with muscle was lead to sever inflammatory reaction. In conclusion, we can use polypropylene mesh and latissmus dorsi muscle for repairing diaphragmatic hernia in dogs but each method have advantage and disadvantage where in spite of polypropylene mesh was characterized by less inflammatory reaction with rapid healing rather than muscle piece but its more expensive.

تقويم الفتق الحجابي المستحدث في الكلاب بدراسة مقارنة بين زراعة شبكة البولي بروبيلين والعضلة الظهرية العريضة

أسامة حازم الحياني، احمد خلف الجبوري، عمر عادل بدر، انتصار رحيم الكناني
كلية الطب البيطري/ جامعة الموصل

الخلاصة

صممت هذه الدراسة لمعرفة الاختلاف بين ترقيع الفتوق الحجابية في الكلاب باستخدام شبكة البولي بـــروبيلين الصناعية غير الممتصة واستخدام الترقيع الذاتي بالعضلة الظهرية العريضة. حيث استخدم في هذه الدراسة اثنا عشر كلبا ومن مختلف الجنسين ثم قسمت الحيوانات إلى مجموعتين، ضمت كل مجموعة ستة كلاب. تم استحداث فتـــق بقطر 5 سم وذلك بإزالة جزء حلقي من الجزء العضلي للحجاب الحاجز في كل الحيوانات وبعدها تركت الحيوانات دون معالجة للأذى المستحدث في الحجاب الحاجز وذلك للحصول على نفس خصائص الفتوق الحجابية من خـــلال الاعتماد على العلامات السريرية والشعاعية لمدة (3) أسابيع لكل حيوان. ففي المجموعة الأولى تم غلـــق الفتـــوق الحجابية باستخدام شبكة البولي بروبيلين وفي المجموعة الثانية عولجت الفتوق باستخدام العضلة الظهرية العريضة.

تم تقييم كل نوع من الروقوعات في الحيوانات من خلال دراسة التغيرات العيانية والمرضية– النسجية كل (7 و21) يوم. أظهرت النتائج إن ترقيع الفتوق الحجابية في المجموعة الأولى أدى إلى تكوين التصاقات اقل من المجموعة الثانية بالإضافة إلى قلة ارتشاح الخلايا الالتهابية وحيدة النواة واندماج الألياف الغراوية الممتدة بين النسيج ألحجابي وشبكة البولي بروبيلين كان أسرع تطورا مقارنة من الترقيع بالعضلة حيث أدى الترقيع بالعضلة إلى تفاعل التهابي شديد. نستنتج مما تقدم إمكانية استخدام شبكة البولي بروبيلين والعضلة الظهرية العريضة في ترقيع الفتوق الحجابية ولكن لكل طريقة فوائد ومساوئ فبالرغم من كون شبكة البولي بروبيلين قليلة التفاعل الالتهابي مع التئام سريع أفضل من العضلة ولكنها الأكثر كلفة.

Introduction

Diaphragmatic hernia is an opening or tear in the diaphragm. The opening allows part of the abdominal organs such as stomach, spleen, liver, and intestines to go up into the chest cavity near the lungs(1). Diaphragmatic injury was first reported by Sennertus in 1541 and was repaired successfully by Riolfi for the first time in 1886 (2). A diaphragmatic hernia may be congenital or traumatic (3). There are several kinds of diaphragmatic hernia such as Bochdalek hernia, also known as a postero-lateral diaphragmatic hernia. It is the most common manifestation of congenital diaphragmatic hernia, accounting for more than 95% of cases. In this instance the diaphragm abnormality is characterized by a hole in the postero-lateral corner of the diaphragm which allows passage of the abdominal viscera into the chest cavity. The majority of Bochdalek hernias (80-85%) occur on the left side of the diaphragm, a large proportion of the remaining cases occur on the right side, and a small fraction are bilateral. In a Bochdalek hernia, the diaphragm may not develop properly, or the intestine may become trapped in the chest cavity as the diaphragm is forming. (4.5,6). Morgagni's Hernia, this is rare anterior defect of the diaphragm and its variably referred to as Morgagni's, retrosternal, or parasternal hernia. Accounting for approximately 2% of all congenital diaphragmatic hernia cases, it is characterized by herniation through the foramina of Morgagni which are located immediately adjacent to the xiphoid process of the sternum. The majority of hernias occur on the right side of the body and are generally asymptomatic. In a Morgagni hernia, the tendon that should develop in the middle of the diaphragm does not develop properly (4,7). Eventration congenital diaphragmatic hernia is used when there is abnormal displacement (i.e. elevation) of part or all of an otherwise intact diaphragm into the chest cavity. This rare type of congenital diaphragmatic hernia occurs because in the region of eventration the diaphragm is thinner, allowing the abdominal viscera to protrude upwards. This thinning is thought to occur because of incomplete muscularisation of the diaphragm, and can be found unilaterally or bilaterally (8). Diaphragmatic hernia is an emergency that requires immediate surgery. Early diagnosis may be difficult. Delayed diagnosis and treatment may result in increased rates of morbidity and mortality dependent upon multiple factors; size of hernia, organs involved, additional birth defects or genetic problems, amount of lung growth, age and size at birth, type of treatments, timing of treatment, complications such as infections and lack of lung function (9). Also obstruction and/or strangulation may occur with herniating organs into thorax if an early diagnosis is missed and treatment is not started promptly. This condition can dramatically increase morbidity and mortality rates in such patients (3,10). The surgeon repairs the hole in the diaphragm. If the hole is small, it may be repaired with stitches, but

in most cases a piece of plastic patch is used to cover the hole in the diaphragm. Many different prosthetic materials have been used for repair of large diaphragmatic hernias, which cannot be primarily repaired (11). Prosthetic materials, including polypropylene mesh, polytetrafluoroethylene (PTFE) patch, reinforced silastic sheet, and polyethylene mesh have been used for repair of large diaphragmatic hernias (12,13,14,15,16). Allogenic lyophylized dura or autologous tissues such as fascia or muscle flaps have also been utilized (17,18,19). The aim of this study was to evaluate the comparison between the efficey of latissmus dorsi muscle segment and polypropylene mesh for repairing diaphragmatic hernia in dogs.

Material and Methods

The study was performed on twelve young dogs (aged from 1-3 years) from both sexes. The animals are allotted into two groups, six animals for each group. A hole as a circular piece about 5 cm in diameter was excised from muscular part at the middle left side of diaphragm in all animals under general anesthesia with a mixture of xylazine and ketamine (5mg/kg and 15 mg/kg, i.m., respectively) and atropine sulfate (0.03 mg/kg i.m.) as premedication before anesthesia (20). The animals was subjected to positive pressure ventilation before thoracotomy operation to prevent collapse of lungs during induced diaphragmatic defect. All animals were kept for about three weeks without any surgical intervention to induce diaphragmatic hernia which was ascertained by radiological examination for each animal (Fig. 1). The defect of diaphragm was treated with two types of graft, polypropylene mesh(synthetic non absorbable graft) and latissmus dorsi muscle segment (natural auto graft). In first group, after anesthesia the animal and prepared the left side of chest for aseptic surgery, the chest was opened by incision between the 10^{th} and 11^{th} intercostal space then the surgical wound was expanded with retractor to provide good exposure for the chest. The organs that entered to the thoracic cavity from belly was returned to the normal position (Fig. 2,3) and the round edge of diaphragmatic hernia was excised. The hernial defect was closed by using polypropylene mesh (Fig. 4). The mesh was sutured with diaphragm by polypropylene suture (3/0) using simple interrupted stitches and then the chest wound was closed by suturing the muscles and skin. A chest tube was placed to allow air, blood, and fluid to drain. While in second group, the hernial defect was repaired by application of circular piece of latissmus dorsi muscle excised from same animal and sutured the diaphragm similar to the first group by polypropylene suture (Fig.5). In this study, the evaluation of each graft efficey was performed by studying the gross and histopathological changes at 7 and 21 days post surgery.

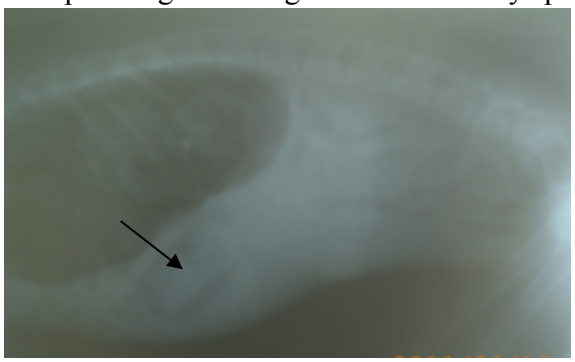

Fig. (1) Shows radiological signs for diaphragmatic hernia in some animals

Fig. (2) Shows some abdominal organs such as stomach and intestine entered into the thoracic cavity

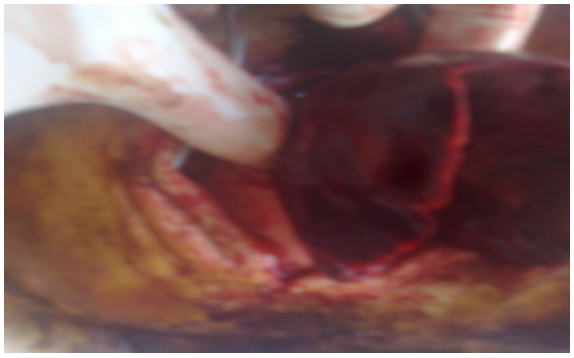

Fig. (3) Shows the liver entered into the thoracic cavity

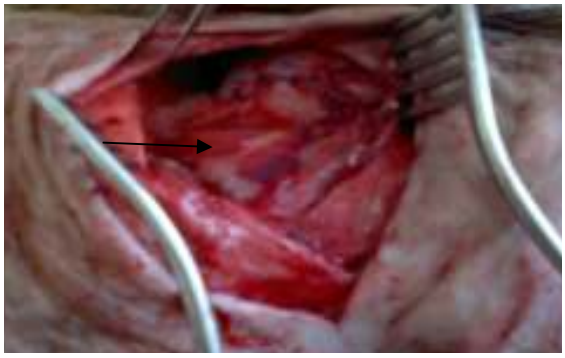

Fig. (4) Shows closure the diaphragmatic hernia with polypropylene mesh

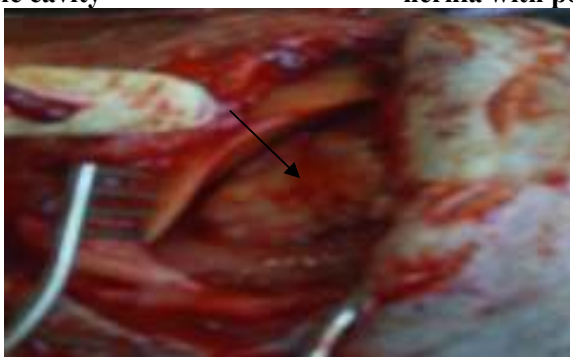

Fig. (5) Shows closure the diaphragmatic hernia with muscle segment

Result

A. Clinical and radiological signs prior to treatment of the defect: The clinical sings was appeared in animals after inducing the defect in the diaphragm includes grasping breathing with difficulty and irregular chest movements, absent of a breath sounds on affected side, bowel sounds heard in the chest and abdomen feels less full on examination by palpation with abdomen appears caved. A chest x-ray was shown some abdominal organs in chest cavity.

B. Gross changes post treatment the defect: Adhesion was formed in both groups, at 7 postoperative days between the internal chest wall and some thoracic organs such as the caudal borders of lung lobe with polypropylene mesh in first group and muscle graft segment in second group. The degree of adhesion in second group was more than in first group. Adhesion was showed also between the grafted area with some abdominal organs such as stomach, omentum and stomach in both groups. In first group, polypropylene mesh was became adhered relatively with the diaphragmatic tissue and the surface of mesh was covered with very thin layer of fibrous tissue . In second group, the muscle segment was bridged slightly with the diaphragmatic tissue also like in first group. Adhesion formation was increased after 21 postoperative days in both groups specially in second group. The polypropylene mesh was disappear slightly because the mesh was covered completely with fibrous tissue while the muscle segment was bridged completely with diaphragmatic tissue also.

C. Histopathological changes: In first group, at 7 postoperative days, the histopathological changes was revealed presence of newly granulation tissue formation (collagen fiber, fibroblast and newly blood vessels) with little infiltration of mononuclear inflammatory

cells. There was hemorrhage, fibrin deposition and little fatty infiltration (Fig. 6). The collagen fiber that have green color when stained with masons trichrome was extended between the polypropylene mesh and muscle bundles of diaphragmatic tissue that lead to bridge between the mesh and muscle of diaphragm (Fig.7,8). While after 21 postoperative days, the collagen fibers was became more mature with significant subside to mononuclear inflammatory cells infiltration (figure 9), and the extension of collagen fibers was more developed (Fig. 10,11). In second group the histopathological changes after 7 postoperative days was reveled also presence newly granulation tissue formation (Fig. 12). There was high infiltration of mononuclear inflammatory cells with hypertrophy of muscular blood vessels, hemorrhage, congestion and more fatty infiltration (Fig. 13). Some area of muscle graft was suffered from myositolysis (Fig.14). There was bridge between muscle segment and diaphragmatic tissue by collagen fibers (Fig. 15). While the changes after 21 postoperative days was represented by maturation of collagen fibers (Fig. 16). The extension of collagen fibers was increased between the muscle segment and diaphragmatic tissue where the fibrous tissue relatively replaced most muscle graft (Fig.17). Infiltration of mononuclear inflammatory cells was subsided like in first group.

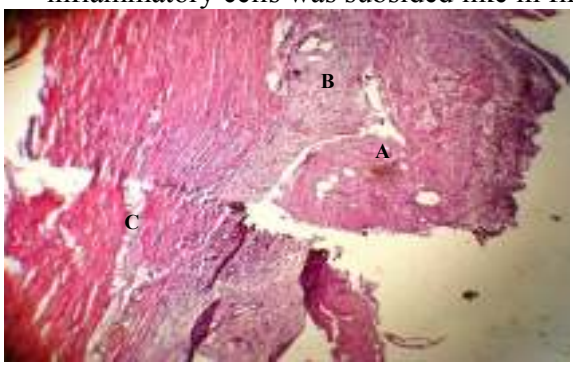

Fig. (6) Photomicrograph of diagrammatic hernia grafted with polypropylene mesh after 7 postoperative days in dog showed newly granulation tissue formation (A), infiltration of mononuclear inflammatory cells (B), and fatty infiltration area (C) (H & E, 35×)

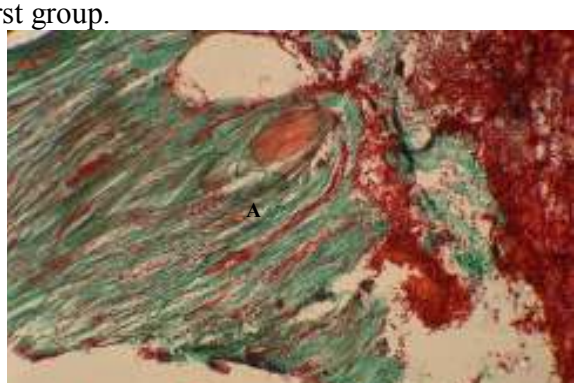

Fig. (7) Photomicrograph of diagrammatic hernia grafted with polypropylene mesh after 7 postoperative days in dog showed extension of collagen fibers within mesh (green color)(A) (Massons trichrome, 90×)

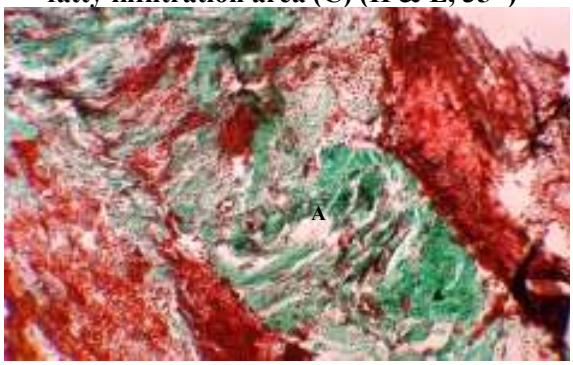

Fig. (8) Photomicrograph of diagrammatic hernia grafted with polypropylene mesh after 7postoperative days in dog showed extension of collagen fibers between mesh and diaphragm (green color)(A) (Massons trichrome, 90×)

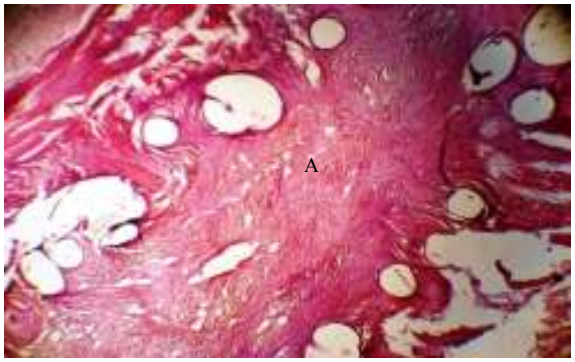

Fig. (9) Photomicrograph of diagrammatic hernia grafted with polypropylene mesh after 21postoperative days in dog showed maturation of collagen fibers (A) (H&E,35×)

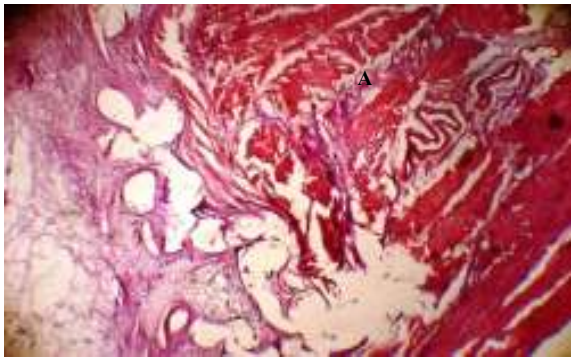

Fig. (10) Photomicrograph of diagrammatic hernia grafted with polypropylene mesh after 21postoperative days in dog showed extension of collagen fibers between muscle bundles of diaphragm (A) (H&E,35×)

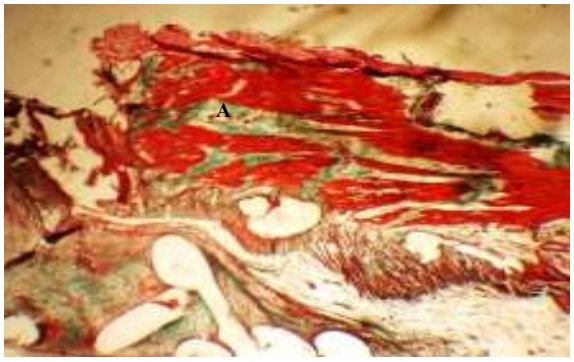

Fig. (11) Photomicrograph of diagrammatic hernia grafted with polypropylene mesh after 21postoperative days in dog showed extension of collagen fibers (green color) (A) (Massons tirchrome, 35×)

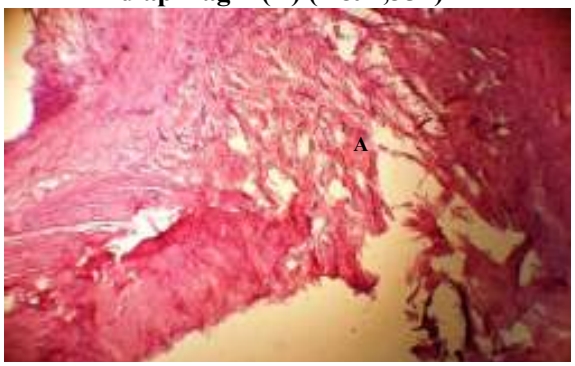

Fig. (12) Photomicrograph of diagrammatic hernia grafted with muscular segment after 7postoperative days in dog showed newly granulation tissue formation (A) (H & E, 35×)

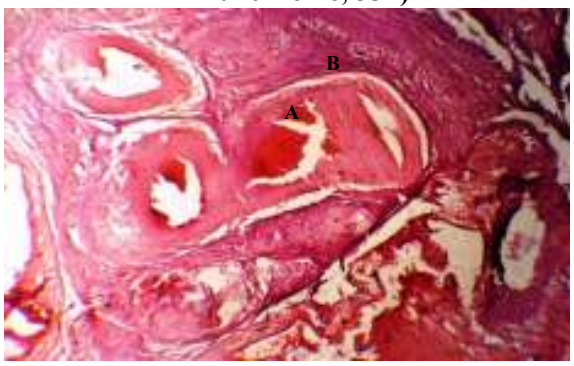

Fig. (13) Photomicrograph of diagrammatic hernia grafted with muscular segment after 7postoperative days in dog showed congested hypertrophy of muscular blood vessels (A) and fatty infiltration (B) (H & E, 35×)

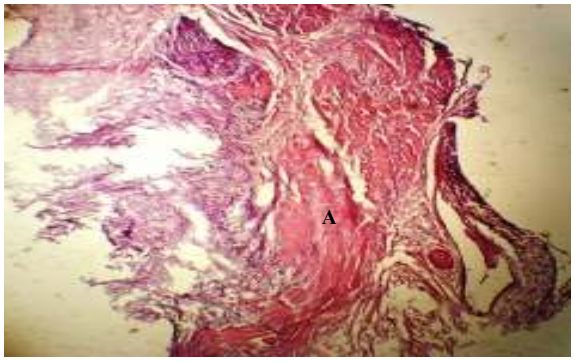

Fig. (14) Photomicrograph of diagrammatic hernia grafted with muscular segment after 7 postoperative days in dog showed area of myositolysis of muscle fibers (A) (H & E, 35×)

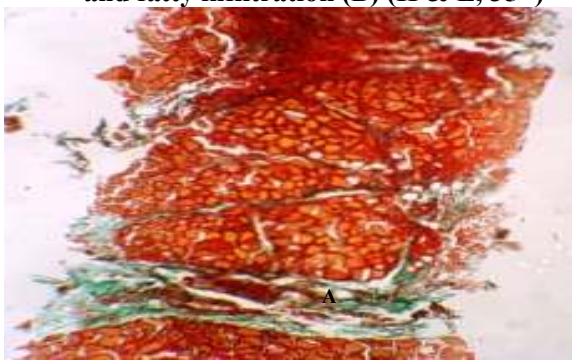

Fig. (15) Photomicrograph of diagrammatic hernia grafted with muscular segment after 7postoperative days in dog showed bridging between muscle graft and diaphragmatic tissue by collagen fibers (A) (green color) (Massons trichrome 90×)

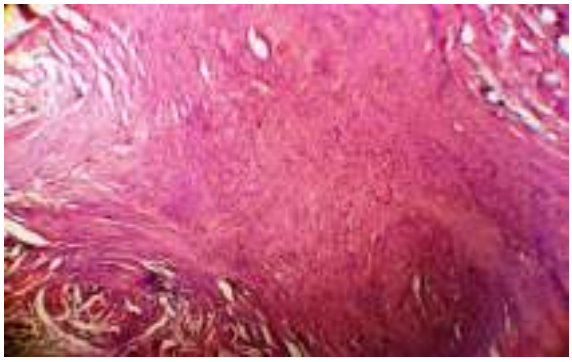

Fig. (16) Photomicrograph of diagrammatic hernia grafted with muscular segment after 21 postoperative days in dog showed maturation the collagen fibers that replaced the grafted muscle (A) (H&E,35×)

Fig. (17) Photomicrograph of diagrammatic hernia grafted with muscular segment after 21 postoperative days in dog showed extension of collagen fibers within muscle implant and diaphragmatic tissue (A) (green color) (Massons tirchorme,35×)

Discussion

Following, the inducing of diaphragmatic defect in dogs and prior to treatment, animals was suffered from difficult breathing and this is due to ineffective movement of the diaphragm and crowding of the lung tissue with some internal abdominal organs, which causes lung collapse, similar observations have been made by (1). In first group after 7 postoperative days adhesion was showed and it increases after 21 days, and this might be due to presence of foreign materials (polypropylene mesh and suture materials) where the implantation the synthetic meshes for repairing hernias lead to granulation tissue and adhesion formation. These adhesions may be disappear gradually or still present. The ratio of adhesion was differed according to the type of mesh, for example the adhesions was increase when used polypropylene mesh and decreased in polytetrafluoroethelene mesh (21, 22). Infiltration of mononuclear inflammatory cells was present because such prosthetic materials may possibly cause allergic reaction and infection (1, 22). The infiltration of inflammatory cells was less in this group because polypropylene mesh was characterized by minimum tissue reaction when implanted even in infected and non infected wound (23). These inflammatory cells was decreased subsequently due to postoperative antibiotic administration. Presence of hemorrhage may be due to refreshing the round edge of diaphragmatic hernia before mesh placement or penetration the tissue with needle suture. In addition the surgery have some risks such as bleeding (1). The extend of fibrous tissue within the mesh was developed rapidly and this extension provided excellent bridging between the mesh and diaphragmatic tissue where several authors (24) was mentioned that the repair of umbilical hernia with polypropylene mesh produce satisfactory result and the mesh was interwoven with the fibrous tissue and indistinguishable from surrounding tissue where the mesh was provide good bed for grew and extend the new granulation tissue and capillaries (25). The presence of new granulation tissue, newly capillaries and infiltration of little inflammatory cells with bridging between mesh and diaphragmatic by mature collagen fibers was indicated to develop of repairing process of the grafted site (26). While in second group, after 7 postoperative days adhesion and infiltration of inflammatory cells was appeared more than in first group and this feature may be because the muscle segment was regarded pure natural protein and this

characteristic lead to increase inflammatory tissue reaction although the use of autologous grafts such as muscle flaps to repair a large defect might minimize the possibility of such complications, but these techniques are rather complicated and invasive, and require prolonged operating times. These may lead to massive bleeding when repair diaphragmatic hernia (27, 28, 29). The extend of new fibrous tissue within the mass of muscle to gave good bridging with diaphragmatic tissue was lower than in mesh because the mesh was designed as a network contain pores, these spaces of mesh was facilitated the extension of collagen fibers but after 21 postoperative days the connection between muscle graft and diaphragm was developed, and this is features was resemble to (30, 31) who's founded the repair of hernias with natural graft lead to connection of the graft with normal tissues by connective tissues consist from collagen fibers and the interposed between the graft and body tissues was increased subsequently due to maturation and increase the formed fibrous tissue. Therefore the replacement of muscle with fibrous tissue is needed long time. Some little area of muscle implant segment was suffered from myositolysis and this may be due to exposure of muscle fibers of muscle graft to hypoxia during excision of it because stopping the innervations of blood supply and as a result fatty infiltration was occurred but this features was disappear by extension of fibrous tissue. However, repairing the hernias with muscle flap produce good result (32).

References

1. Ehrlich, P. F. & Coran, A. G. 2007. Diaphragmatic hernia. In: Kliegman, R. M.; Behrman, R. E.; Jenson, H. B. & Stanton, B. F. Nelson Textbook of Pediatrics. 18th (ed.) Philadelphia, Pa: Saunders Elsevier. Chap. 101:1-3.
2. Turhan, K.; Makay, O.; Cakan, A.; Samancilar, O.; Firat, O.; Icoz, G. & Cagirici U. 2008. Traumatic diaphragmatic rupture. Eur. J. Cardio. Thorac. Surg., 33:1082-1085.
3. Ozkan, S.; Akinoglu, A.; Yagmur, O.; Alabaz, O.; Demiryurek, H. & Demircan, O. 1998. Blunt and penetrating ruptures of the diaphragm. Ulus Travma Acil Cerrahi Derg., 4:253-256.
4. Torfs, C. P.; Curry, C. J.; Bateson, T. F. & Honoré, L. H. 1992.A population-based study of congenital diaphragmatic hernia. Teratol., 46 (6): 555-565.
5. Yang, W.; Carmichael, S. L.; Harris, J. A. & Shaw, G. M. 2006. Epidemiologic characteristics of congenital diaphragmatic hernia among 2.5 million California births, 1989-1997. Birth Defects Res. Part a Clin. Mol. Teratol., 76(3): 170-174.
6. Lally, K. P.; Lally, P. A. & Lasky, R. E. 2007. Defect size determines survival in infants with congenital diaphragmatic hernia. Pediatrics., 120 (3): e651-e657.
7. Eren, S. & Ciriş, F. 2005. Diaphragmatic hernia: diagnostic approaches with review of the literature. Europ. J. Radiol., 54 (3): 448-459.
8. Rais-Bahrami, K.; Gilbert, J. C.; Hartman, G. E.; Chandra, R. S. & Short, B. L. 1996. Right diaphragmatic eventration simulating a congenital diaphragmatic hernia. Am. J. Perinatol., 13 (4): 241-243.
9. Kozak, O.; Mentes, O.; Harlak, A.; Yigit, T.; Kilbas, Z.; Aslan, I.; Akin, M. & Bozlar, U. 2008. Late presentation of blunt right diaphragmatic rupture (hepatic hernia). Am. J. Emerg. Med., 26:638.e3-638.e5.
10. Alimoglu, O.; Eryilmaz, R.; Sahin, M. & Ozsoy, M. S. 2004. Delayed traumatic diaphragmatic hernias presenting with strangulation. Hernia., 8:393-396.

11. Bekdash, B. & Lakhoo, B. S. K. 2009. Recurrent late complications following congenital diaphragmatic hernia repair with prosthetic patches: a case series. J. Med. Case Reports., 3:7237.
12. Newman, B. M.; Jewett, T. C.; Lewis, A.; Cerny, F.; Khan, A.; Karp, M. & Cooney, D. R. 1985. Prosthetic materials and muscle flaps in the repair of extensive diaphragmatic defects: an experimental study. J. Pediatr. Surg., 20:362-367.
13. Lally, K. P.; Cheu, H. W. & Vazquez, W. D. 1993. Prosthetic diaphragm reconstruction in the growing animal. J. Pediatr. Surg., 28:45-47.
14. Clark, R. H.; Hardin, W. D. Jr.; Hirschl, R. B.; Jaksic, T.; Lally, K. P.; Langham, M. R. Jr. & Wilson, J. M. 1998. Current surgical management of congenital diaphragmatic hernia: a report from the Congenital Diaphragmatic Hernia Study Group. J. Pediatr. Surg., 33:1004-1009.
15. Kimber, C. P.; Dunkley, M. P.; Haddock, G.; Robertson, L.; Carey, F. A. & Cuschieri, A. 2000. Patch incorporation in diaphragmatic hernia. J. Pediatr. Surg., 35:120-123.
16. Saltzman, D. A.; Ennis, J. S.; Mehall, J. R.; Jackson, R. J.; Smith, S. D. & Wagner, C. W. 2001. Recurrent congenital diaphragmatic hernia: A novel repair. J. Pediatr. Surg., 36:1768-1769.
17. Koot, V. C. M.; Bergmeijer, J. G. & Molenaar, J. C. 1993. Lyophylized dura patch repair of congenital diaphragmatic hernia: occurrences of relapses. J. Pediatr. Surg., 28:667-668.
18. Sydorak, R. M.; Hoffman, W.; Lee, H.; Yingling, C. D.; Longaker, M.; Chang, J.; Smith, B.; Harrison, M. R. & Albanese, C. T. 2003. Reversed latissimus dorsi muscle flap for repair of recurrent congenital diaphragmatic hernia. J. Pediatr. Surg., 38:296- 300.
19. Scaife, E. R.; Johnson, D. G.; Meyers, R. L.; Johnson, S. M. & Matlak, M. E. 2003. The split abdominal wall muscle flap-a simple, mesh-free approach to repair large diaphragmatic hernia. J. Pediatr. Surg., 38:1748-1751.
20. Al-Asadi, R. N. & Shnin, H. 1987. The use of ketamine and xylazine combination as a general anesthesia for dogs. M.Sc. Thesis, College of Vet. Med., Uni. of Baghdad.
21. Trostle, S. S. & Rosin, E. 1994. Selection of prosthetic mesh implants. The Compendium. Small Anim., 16(9):1147-1155.
22. Moss, R. L.; Chen, C. M. & Harrison, M. R. 1992. Prosthetic patch durability in congenital diaphragmatic hernia: a long-term follow-up study. J. Pediatr. Surg., 27:754-756.
23. Usher, I. C.; Fries, J. G.; Ochsner, J. I. & Tuttle, L. L. D. 1959. Marlex mesh. a new plastic mesh for repairning tissue defects. Clinical studies. Archives Surgery., 78-138.
24. Tulleners, E. P. & Fretz, P. B. 1983. Prosthetic repair of large abdominal defects in horses and food animals. J. Am. Vet. Med. Assoc., 82:258-262.
25. Rajendran, E. I.; Gopal, M. S. & David, G. 1974. Prosthetic hernioplasty with polyethylene mesh in procine umbilical hernia. Indian Vet. J., 51:67-69.

26. Fauza, D. O.; Marler, J. J.; Koka, R.; Forse, R. A.; Mayer, J. E. & Vacanti, J. P. 2001. Fetal tissue engineering: diaphragmatic replacement. J. Pediatr. Surg., 36:146-151.
27. Kanade, M. G.; Kumer, A. & Sharma, S. N. 1988. Repair of abdominal defects by stainless steel and nylon mesh implants in buffaloes; histological and histochemical evaluation. Ind. J. Anim. Sci., 58(4):415-419.
28. Dalla Vecchia, L.; Engum, S.; Kogon, B.; Jensen, E.; Davis, M. & Grosfeld, J. 1999. Evaluation of small intestine submucosa and acellular dermis as diaphragmatic prostheses. J. Pediatr. Surg., 34:167-171.
29. Sandoval, J. A.; Lou, D.; Engum, S. A.; Fisher, L. M.; Bouchard, C. M.; Davis, M. M. & Grosfeld, J. L. 2006. The whole truth: comparative analysis of diaphragmatic hernia repair using 4-ply vs 8-ply small intestinalsubmucosa in a growing animal model. J. Pediatr. Surg., 41:518-523.
30. Parizek, J.; Husek, Z.; Mericka, P.; Terr, J.; Nemecek, S.; Spacek, J.; Nemecova, J. & Suba, P. 1996. Ovine pericardium: a new material for duraplasty. J. Eur. Surg., 48:508-513.
31. Parizek, J.; Mericka, P.; Suba, P.; Spacek, J.; Nemecek, S.; Nemecova, J.; Serel, M. & Elias, P. 1997. Detailed evaluation of 2959 allogenic and xenogenic dense connective tissue grafts (fasia lata, pericardium and duramater) used in the conrage of 20 years for duraplasty in neurosurjery. Acta. Neuro. Chir. (Wein)., 139:827-838.
32. Werthern, C. J.; Von Montavon, P. M. & Von Waethern, C. J. 1996. Reinforcement of caudal abdominal hernia by a pectineus muscle flap in dogs and cats. Kleintierproxis., 41:169-176.