

Reconstruction of Chest Wall Defects After Rib Tumor Resection: A Comparison of Autogenous, Prosthetic, and Composite Techniques in 44 Dogs

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Objective—To compare short- and long-term outcome and complications of chest wall reconstruction in dogs using autogenous, prosthetic, and composite autogenous–prosthetic techniques.

Study Design—Historical cohort.

Animals—Dogs (n = 44) with spontaneous tumors arising from or involving the chest wall.

Methods—Medical records were reviewed for dogs with rib and/or sternal tumors treated by chest wall resection and reconstruction. Signalment, preoperative clinical features, intraoperative findings and complications, reconstruction technique (autogenous muscle flap, prosthetic mesh, or composite autogenous–prosthetic technique), and short- (≤ 14 days) and long-term (> 14 days) postoperative complications were determined from the medical records and telephone contact with owners and referring veterinarians. Associations between chest wall reconstruction technique and postoperative complications were tested with Cox proportional hazards.

Results—Chest wall defects were reconstructed with autogenous muscle flaps (29 dogs), prosthetic mesh (3), and a composite technique of prosthetic mesh and either autogenous muscle or omental pedicle flap (12). Early postoperative complications were recorded in 8 dogs (18.2%) and included seroma (5) and pleural effusion and peripheral edema (3). One dog had a late complication (2.3%) with a mesh-related infection 767 days postoperatively. Overall, complications occurred in 10.3% of autogenous, 25.0% of composite, and 66.7% of prosthetic reconstructions. Chest wall reconstruction with Marlex mesh alone was associated with a significantly increased risk of postoperative complications compared with autogenous reconstruction ($P = .027$). Reconstruction of sternal defects (3), 2 of which were performed with Marlex mesh alone, was associated with a significantly increased risk of complications compared with lateral chest wall reconstructions ($P = .037$).

Conclusions—Large chest wall defects can be reconstructed with autogenous and composite techniques, but prosthetic mesh should be covered with well-vascularized autogenous muscle or omentum to decrease the risk of postoperative complications. Sternal defects should be reconstructed with rigid techniques.

Clinical Relevance—Chest wall reconstruction with autogenous muscle flaps or a combination of autogenous techniques with prosthetic mesh is associated with a low rate of infection and other complications.

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INTRODUCTION

CHEST WALL resection is commonly performed in dogs for the management of rib tumors. Most rib tumors are primary malignant sarcomas, with osteosarcoma (OSA) and chondrosarcoma (CSA) being the most common rib tumors.¹⁻⁶ Surgical resection of ≥ 3 cm margins of normal tissue is recommended for the management of primary rib sarcomas because of their aggressive local behavior, and this frequently involves multiple ribs and occasionally adjacent organs and structures.³⁻⁸ Primary repair of chest wall defects is rarely possible because of the large size of the defect, so autogenous and prosthetic techniques have been used for reconstruction. The objectives of chest wall reconstruction are to fill the defect and reduce dead space, establish an airtight seal of the pleural cavity, and provide sufficient rigidity to prevent respiratory compromise and protect intrathoracic structures.⁹⁻¹⁴

Chest wall reconstructive techniques described in dogs include autogenous latissimus dorsi muscle and myocutaneous flaps^{3,5,6,15}; external abdominal oblique muscle flap, omental pedicle flap^{5,8} and diaphragmatic advancement^{3,5,6,16}; and prosthetic mesh^{3,5,6-8,17,18}; mesh-methylmethacrylate sandwich^{19,20}; and rib replacement with rib grafts or spinal plates.^{5,21} In dogs, selection of chest wall reconstructive technique depends on size and location of the defect. The latissimus dorsi muscle or myocutaneous flap is the most commonly used autogenous technique for reconstruction of chest wall defects^{3,5,6}; however, this may not be a viable option for some defects because the pedicled flap may be too small to completely fill large chest wall defects; the arc of rotation of the latissimus dorsi muscle flap may not reach ventral and caudal chest wall defects; and either the dominant vascular pedicle, the thoracodorsal artery and vein, or muscle itself may be involved in the neoplastic process or wide excision of the rib tumor.¹⁸ In such cases, prosthetic mesh is commonly used to reconstruct chest wall defects.^{5,6,18} Nonabsorbable polypropylene mesh (Marlex) is most commonly used in dogs,^{3,5-8,18,21} but Prolene, polytetrafluoroethylene (PTFE), and vicryl (polyglactin) mesh are also used to reconstruct chest wall defects in humans.^{9,10,13} Many surgeons avoid the use of nonabsorbable mesh because of the risk of complications, particularly infection.^{14,22,23} Despite this concern, retrospective clinical reviews in dogs and humans show that prosthetic mesh used for chest wall reconstruction is associated with a low rate of infection and other complications.^{3,5-7,11,12,18,22,24}

Chest wall resection and reconstruction has been described for the management of primary malignant rib tumors in dogs³⁻⁶; however, a comparison of different chest wall reconstructive techniques has not been investigated. We compared short- and long-term outcome and

complications of chest wall reconstruction using autogenous, prosthetic, and composite autogenous-prosthetic techniques.

MATERIALS AND METHODS

Inclusion Criteria

Medical records (January 1992–December 2005) from Colorado State University Veterinary Teaching Hospital and Ontario Veterinary College were reviewed for dogs with rib and/or sternal tumors treated by chest wall resection and reconstruction. Dogs where diaphragmatic advancement was used as the sole technique after resection of caudal chest wall tumors were excluded from analysis.

Retrieved data included signalment, physical examination findings, abnormal blood test results, thoracic imaging (radiographs, computed tomography [CT], magnetic resonance imaging [MRI], and ultrasound) findings, surgical observations, chest wall reconstruction technique, and postoperative complications. Imaging findings included location of the tumor (left or right side, and rib number). Surgical findings included number of ribs and/or sternbrae resected, tumor invasion into adjacent organs (i.e., pericardium or lungs), metastatic disease, and chest wall reconstruction technique. Chest wall reconstruction techniques were defined as autogenous, prosthetic, or composite.

Reconstruction Techniques

Autogenous reconstruction techniques included latissimus dorsi and deep pectoral muscle flaps, or direct rib suture.

Latissimus Dorsi Muscle Flap. This is a type V muscle flap based on the thoracodorsal artery arising at the caudal depression of the shoulder.^{25,26} The dorsal border of the flap extends from ventral to the acromion and caudal border of the triceps muscles to the head of the 13th rib.^{25,26} The ventral border was either the ventral border of the muscle, if intact, or the incised edge if part of the latissimus dorsi muscle was excised en bloc with the rib tumor. Perforating intercostal vessels were ligated and divided allowing the elevation of the flap and rotation into the chest wall defect (Fig 1).

Deep Pectoral Muscle Flap. This is a type V muscle flap which can be rotated cranially and dorsally based on its lateral thoracic pedicle, or, as in our cases, ventrally across the midline based on segmental branches of the internal thoracic artery.²⁶ The deep pectoral muscle flap was elevated by incising its sternal attachment, undermining the muscle belly while preserving the cranial portion of the sternal attachment and as many branches of the internal thoracic artery as possible, and rotating the muscle flap across the ventral midline into a contralateral chest wall defect.²⁶ Both types of muscle flaps were sutured into the chest wall defect under moderate tension with monofilament absorbable suture material.

Prosthetic reconstruction involved the use of a nonabsorbable polypropylene mesh (Marlex[®], CR Bard, Murray Hill, NJ). For these dogs, the size of the Marlex mesh was tailored to the size of the chest wall defect so that the edges were

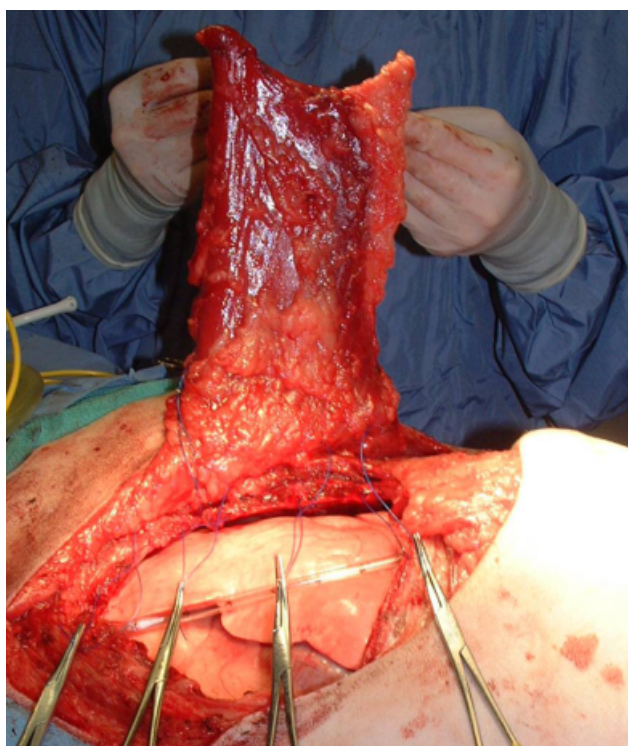


Fig 1. Intraoperative image of an elevated latissimus dorsi muscle flap for reconstruction of a chest wall defect after resection of 4 ribs for excision of a primary rib osteosarcoma in a dog.

doubled over providing a double-layer thickness for suturing to adjacent host tissue.⁷ The mesh was sutured under mild tension either to the pleural or lateral surface of the defect using either absorbable or nonabsorbable monofilament suture material.⁷ Composite reconstruction techniques involved a combination of both an autogenous muscle or omental pedicle flap and Marlex mesh (Fig 2).⁸

Postoperative Care

A thoracostomy tube was inserted in all dogs. Postoperative management included the administration of opioid and nonsteroidal anti-inflammatory analgesia, intrapleural analgesia through the thoracostomy tube, regular aspiration of the thoracostomy tube with recording of the amount of air and fluid aspirated, and monitoring of oxygenation and ventilation with respiratory rate and pattern, pulse oximetry, and blood gas analyses. Oxygen supplementation was provided if indicated by either nasal catheter or oxygen cage. Thoracostomy tubes were removed when the volume of pleural fluid decreased to <5 mL/kg/day. For dogs treated with adjuvant chemotherapy, the chemotherapy protocol was recorded.

Surgical Complications

Surgical complications were determined from medical records and telephone interview of the referring veterinarian and

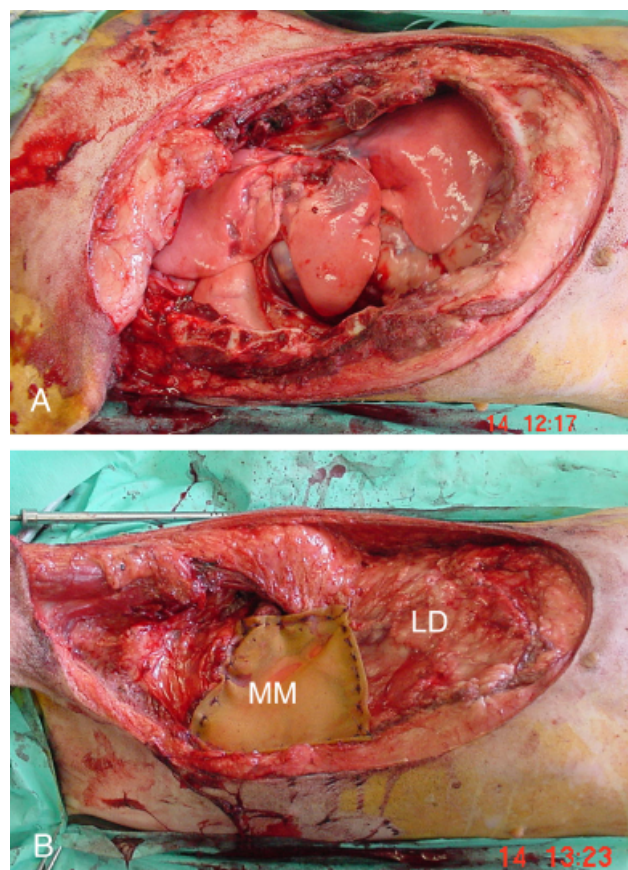


Fig 2. (A) A large chest wall defect in a dog after resection of 6 ribs for excision of a primary rib chondrosarcoma, including en bloc partial lung lobectomy and pericardectomy. (B) The chest wall defect was reconstructed with a composite technique of Marlex mesh (MM) in the cranial half of the defect and a latissimus dorsi muscle flap (LD) in the caudal half of the defect because the size of the defect was too large to be reconstructed with the latissimus dorsi muscle flap alone.

owner. Surgical complications were defined as early (≤ 14 days of surgery) and late (> 14 days after surgery). Cox proportional hazards and logistical regression were used to test if chest wall reconstruction technique (autogenous, prosthetic, composite) increased the risk of early, late, and overall surgical complications, and to determine which factors had an impact on the development of surgical complications. A P -value $< .05$ was considered significant. Post-hoc power analysis was performed for all statistically nonsignificant results.

RESULTS

Signalment

Rib resection and chest wall reconstruction was performed in 44 dogs (January 1992–December 2005) with chest wall tumors. Breeds were 10 each of Golden

Retrievers and mix breed dogs; 6 Labrador Retrievers; 2 each of Bassett Hounds, Dobermans, and German Short-Haired Pointers; and 1 each of an Australian Shepherd, Boxer, Briard, British Bulldog, American Cocker Spaniel, Rough-Coated Collie, Irish Setter, Giant Pyrennes, Rottweiler, Giant Schnauzer, Shar Pei, and Springer Spaniel. Twenty-one dogs were female (20 spayed) and 23 were male (17 neutered). Median age at admission was 8 years (mean 7.4 years; range 1–12 years) and median weight was 31.7 kg (mean 31.9 kg; range 9.6–54.0 kg). Reasons for admission included a palpable chest wall mass ($n=27$), respiratory signs (4), thoracic limb lameness (2), palpable mass and lameness (6) or respiratory signs (3), and nonspecific signs (2).

Diagnostic Tests

All dogs were staged with hematology, serum biochemical profile, and thoracic radiographs. Other staging tests included whole-body scintigraphic bone scans (12), thoracic ultrasonography (6), CT (5) or MRI (3), and abdominal radiographs (2). Hematologic abnormalities included anemia (5), leukocytosis (4), mature neutrophilia (7) or neutrophilia with left shift (1), and lymphopenia (1). Alkaline phosphatase was elevated in 21 dogs (range 148–1898 IU/L; reference interval 20–142 IU/L). Other biochemical abnormalities included increased concentrations of alanine transferase (3), aspartate transferase (3), gamma-glutamyltransferase (1), and creatine kinase (7).

Tumor Location

Tumor location was determined from thoracic imaging techniques. Thirty-nine tumors originated from either the ribs (37) or sternum (2). Multiple ribs were involved in 2 dogs (7th–9th ribs [1] and 9th–11th ribs [1]). Sternal tumors originated from either the 2nd sternebra (1) or 2nd and 3rd sternebrae (1). Five dogs had tumors of soft tissue origin with no radiographic evidence of bone involvement; 4 dogs with subcutaneous tumors and 1 dog with an invasive cranial mediastinal tumor. Pulmonary metastasis was suspected in 2 dogs, but none of the 12 dogs staged with whole-body bone scans had evidence of secondary bone lesions.

Chest Wall Resection and Reconstruction

Rib tumors were excised with a minimum of 1 rib cranial and caudal to the tumor and a ≥ 3 cm dorsal and ventral to the tumor. Sternal tumors were excised with a minimum of 1 sternebra cranial and caudal to the tumor and 3 cm lateral to the sternal mass. Subcutaneous chest wall tumors were excised with ≥ 3 cm lateral margins

and 1 fascial layer for deep margins, including ribs. The median number of ribs excised with the chest wall tumor was 3 ribs (mean, 3.5 ribs; range, 2–6 ribs). A median of 3 ribs were resected in dogs with rib tumors (mean, 3.5 ribs; range, 2–6 ribs), 5 ribs and sternebrae in dogs with sternal tumors (mean, 5.0 ribs and sternebrae; range, 4–6 ribs and sternebrae), and 3 ribs in dogs with soft tissue tumors (mean, 3.3 ribs; range, 2–4 ribs). The 1st rib was included in the chest wall resection in 5 dogs. Contiguous tissue was excised en bloc with the chest wall tumor, including lung lobe (12), pericardium (5), diaphragm (2), sternum (2), and cranial mediastinal mass (1). One dog with a lytic metacarpal lesion was also treated with digit amputation.

The chest wall defect was reconstructed using autogenous techniques (29 dogs), prosthetic mesh (3), and composite techniques (12). Choice of reconstruction technique was based on surgeon preference and, to a lesser extent, location and size of the defect. Autogenous chest wall techniques included a latissimus dorsi muscle flap (22), latissimus dorsi muscle flap combined with diaphragmatic advancement (3), deep pectoral muscle flap (2), and primary rib suturing (2). Composite techniques involved the combination of Marlex mesh with a latissimus dorsi muscle flap (9), diaphragmatic advancement (1), or omental pedicle flap (2).

Median number of ribs resected in dogs that had reconstruction with autogenous techniques was 3 (mean, 3.3 ribs; range, 2–6 ribs); with prosthetic mesh, 4 (mean, 4.3 ribs; range, 3–6 ribs); and with composite techniques, 4 (mean, 4.0 ribs; range, 3–6 ribs; Fig 3).

Complications

Intraoperative complications included estimated blood loss of $>10\%$ blood volume (13 dogs) and hypotension

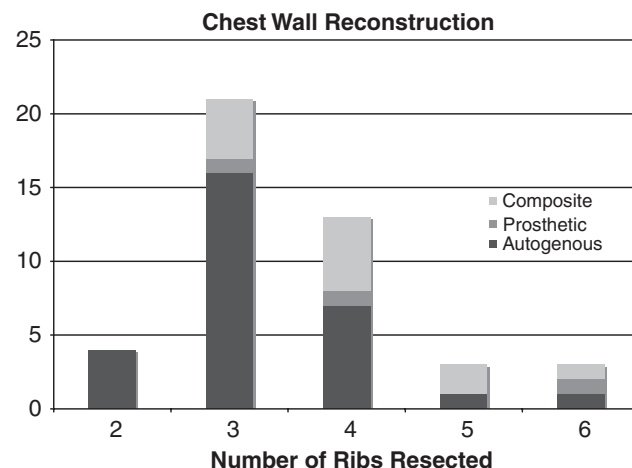


Fig 3. Graph indicating the surgical technique used to reconstruct chest wall defects based on the number of ribs resected.

(15). Matched whole blood transfusions were administered to 3 dogs, including 2 dogs with intraoperative blood loss and 1 dog with pre-existing hemothorax secondary to a ruptured hemangiosarcoma. Blood loss and hypotension were managed with a combination of crystalloid and colloid fluids, and pressor agents like dopamine or dobutamine.

In the immediate postoperative period, 24 dogs (54.5%) were administered supplemental oxygen for a median of 19.5 hours (mean, 25.0 hours; range, 2–100 hours). Thoracostomy tubes were removed after a median of 30.0 hours (mean, 39.3 hours; range, 4–100 hours).

Postoperative complications occurred in 8 dogs (18.2%). Early complications in 8 dogs (18.2%) included incisional seroma (5), pleural effusion (3), peripheral edema (3), and pulmonary edema (1). Incisional seromas occurred in 2 dogs after composite technique reconstruction, 2 dogs with prosthetic mesh, and 1 dog with an autogenous latissimus dorsi muscle flap. Seromas were diagnosed based on their gross appearance (fluctuant mass deep to the surgical incision) and absence of other characteristics of infection (i.e., pain and heat). Seromas were managed with warm compresses and/or bandaging, and these resolved spontaneously without requiring needle or surgical drainage.

Two dogs with pleural effusion also had peripheral edema and neither dog had either hypoalbuminemia or volume overload. Pleural effusion was characterized as a modified transudate in 2 dogs and hemothorax in 1 dog (this dog died on the day of surgery). On necropsy, neoplastic or iatrogenic trauma to the internal thoracic artery was identified as the source of hemorrhage. The other 2 dogs with pleural effusion were euthanatized 5 days postoperatively because of continuous and unresponsive serosanguineous effusion. Both dogs had sternectomy (1 for a sternal tumor, 1 combined with resection of 6 ribs for a large tumor involving both the ribs and sternum). Both chest wall defects were reconstructed with Marlex mesh alone.

One dog had a late complication with an infection developing at the surgery site 767 days postoperatively. A composite technique of Marlex mesh and autogenous latissimus dorsi muscle flap was used to reconstruct the chest wall defect after resection of 4 ribs. This dog also developed an incisional seroma as an early complication. *Staphylococcus intermedius* and a β -hemolytic *Streptococcus* sp. were cultured from the wound and the dog responded to culture-directed antibiotic therapy (amoxicillin-clavulanic acid), but infection recurred when antibiotics were stopped. The dog was euthanatized 1232 days postoperatively because of persistent and recurrent infection at the surgery site.

Overall, complications occurred in 3 dogs with autogenous reconstruction (10.3%), 3 dogs with composite

reconstruction techniques (25%), and 2 dogs reconstructed with Marlex mesh (66.7%). Overall, prosthetic mesh reconstruction of chest wall defects was associated with a significantly increased risk of complications compared with autogenous techniques ($P = .027$; odds ratio [OR] 12.83; 95% confidence interval [CI] 1.192–156.01), but not composite techniques ($P = .190$; OR 0.337; CI –2.66 to 0.477; power = 11.6). The odds for postoperative complications were 12.8 times more likely for prosthetic reconstructions and 3.0 times more likely for composite reconstruction compared with autogenous techniques. The risk of early complications was significantly increased after reconstruction of sternal defects compared with rib defects ($P = .037$). The risk of complications was not significantly increased as the number of resected ribs increased ($P = .0775$; OR 1.192; CI 0.862–4.519; power = 42.49).

DISCUSSION

We used autogenous, prosthetic, and composite autogenous–prosthetic techniques to reconstruct chest wall defects after wide excision of rib tumors. Selection of reconstruction technique was based on surgeon preference and, to a lesser extent, location and size of the defect. In humans, the reconstruction technique is primarily determined by location and size of the chest wall defect. Autogenous techniques alone are sufficient for anterolateral chest wall defects < 5 cm diameter or < 3 resected ribs, and for posterior chest wall defects < 10 cm diameter^{9–12,24,27,28}, however, greater rigidity is recommended for reconstruction of sternal and larger chest wall defects.^{9–12,24,28} Meshes and mesh-methylmethacrylate sandwiches are preferred for these reconstructions as the additional rigidity reduces paradoxical chest wall motion and resultant ventilatory compromise, and provides superior protection of intrathoracic organs and vessels.^{9–12,28} However, the necessity for rigid chest wall reconstruction in dogs is questionable because paradoxical chest wall motion does not affect ventilatory function in either experimental models of traumatic flail chest or in clinical reports of chest wall reconstruction in dogs.^{14,29–31}

Autogenous Techniques

Autogenous techniques used by us to reconstruct chest wall defects were latissimus dorsi and deep pectoral muscle flaps, and primary suturing of the ribs. Chest wall defects involving the 9th–13th ribs do not necessarily require reconstruction as normal thoracic physiology and function can be restored by advancement of the diaphragm alone.^{3,5,6,16} Chest wall defects managed by diaphragmatic advancement alone were excluded from our study because the chest wall was not reconstructed.

Primary suturing was performed in 2 dogs early in this study after resection of 2 and 3 ribs. Suturing of the ribs without supplemental reconstruction is only possible after resection of a small number of ribs.^{4,5} Primary suturing is acceptable if wide excision of the tumor is possible with minimal rib resection, but wide excision of the tumor should not be compromised because of concerns regarding closure of the defect, especially with the numerous options available for reconstruction of large chest wall defects. This is highlighted by an earlier report of chest wall resection for treatment of primary rib sarcomas in dogs where survival rate was decreased when chest wall defects were closed by primary rib suture (0% 44-week survival rate) compared with reconstructive techniques (40% 44-week survival rate).⁴

Pedicled muscle flaps are ideal for reconstruction of chest wall defects because of their large size and good survival rates. The latissimus dorsi muscle was the most common autogenous flap for reconstruction of chest wall defects in our dogs, and also other reports in both dogs and people.^{3,5,6,9,13} The latissimus dorsi is a flat, triangular muscle covering the dorsal half of the lateral chest wall. This type V muscle flap is commonly used for reconstruction of chest wall defects because of its location relative to the chest wall, large size, good arc of rotation to permit coverage of most chest wall defects, and excellent flap survival based on the thoracodorsal artery and extensive anastomoses between its intercostal and thoracodorsal pedicles.²⁶ Chest wall defects of ≤ 6 ribs were reconstructed with latissimus dorsi muscle flaps in our dogs. The latissimus dorsi can be harvested either as a muscle or a myocutaneous flap.¹⁴ Latissimus dorsi myocutaneous flaps were not used in our dogs, and are rarely indicated, because all skin defects could be closed primarily.¹⁴

The deep pectoral muscle was elevated and mobilized to fill ventral chest wall and sternal defects in 2 dogs. The deep pectoral muscle is a suitable muscle flap in dogs because of its accessibility and favorable vascular pattern.²⁶ The deep pectoral muscle is a type V muscle flap that can be rotated cranially and dorsally based on its lateral thoracic pedicle, or, as in our dogs, ventrally across the midline based on segmental branches of the internal thoracic artery.²⁶ The pectoralis major muscle flap is commonly used in humans,^{9,13} but to our knowledge, the deep pectoral muscle flap has not been previously reported for reconstruction of chest wall defects in dogs.

Reconstruction with Prosthetic Materials

Marlex mesh was used alone in 3 dogs or as a composite with autogenous muscle or omental flaps in 12 dogs for reconstruction of chest wall defects. The decision

to use prosthetic mesh was based on surgeon preference, but mesh was occasionally used when latissimus dorsi muscle flaps were unable to completely reconstruct the chest wall defect. This occurred when the muscle flap was too small relative to the size of the defect (Fig 2) or because partial excision of the muscle was required to achieve wide surgical margins, or the defect was beyond the arc of rotation of the harvested muscle flap. Meshes are used for reconstruction of larger chest wall defects in humans because they are associated with a significantly decreased rate of respiratory complications and shorter hospital stays when compared with autogenous muscle flap reconstructions because mesh provides additional rigidity when sutured under tension.^{9,12,22,28}

The ideal characteristics of prosthetic material for chest wall reconstruction include rigidity, malleability, inertness, radiolucency, and resistance to infection.^{11,12,23} Marlex mesh is constructed of knitted nonabsorbable monofilament polypropylene²³ and was the only type of mesh used for chest wall reconstruction in these dogs. Marlex mesh has a high tensile strength and low permeability to liquids and gases.^{18,23} The pore size of 200–800 μm permits the rapid ingrowth of vascularized tissue and, by 6 weeks, Marlex mesh is infiltrated with 3–4 mm thick fibrous tissue.^{23,32,33} By 6 months, Marlex mesh is incorporated with no loss of tensile strength or fragmentation of mesh material.^{34–36} Other meshes commonly used for chest wall reconstruction in people include Prolene, PTFE, and polyglactin.^{9,10,13} Polyglactin is an absorbable mesh and indicated for reconstruction of contaminated wounds.¹³ PTFE is strong, resistant to infection, and impervious to air and fluids and hence has ideal characteristics for chest wall reconstruction; however, it is very expensive.^{9,23} Marlex and Prolene meshes, while not impervious to air and fluids, are just as effective as PTFE for chest wall reconstruction.^{9,10} Prolene mesh is often preferred to Marlex mesh in humans, despite both being constructed from polypropylene, because Prolene mesh is constructed from double knitted polypropylene and thus resists stretching in all directions, rather than unidirectional as in Marlex mesh.^{9,10}

Complications

The overall complication rate was 18.2%, which is comparable to other reports of chest wall reconstruction in dogs and humans.^{3,5,12,18,22,24,37} In humans, respiratory complications are more common and include prolonged mechanical ventilation, pneumonia, acute respiratory distress syndrome, and pulmonary hypofunction.^{11,12,22,24} We did not specifically assess postoperative pulmonary function or paradoxical motion of the reconstructed chest wall in these dogs, but no dog required postoperative mechanical ventilation and respiratory pattern and blood

gas analyses were typical of dogs treated with any type of open chest surgical procedure (including thoracotomy).³⁸ Pulmonary function was also normal in a small number of dogs after chest wall reconstruction with a latissimus dorsi myocutaneous flap.¹⁴ Only 1 dog in our study had a respiratory complication (pulmonary edema) and this resolved with diuretic treatment. Respiratory complications are also rare in other studies of chest wall reconstruction in dogs. Paradoxical motion of the reconstructed chest wall has been reported in dogs,^{8,14} but, in both experimental and clinical studies, paradoxical motion in the absence of underlying pulmonary trauma does not result in pulmonary hypofunction in dogs.^{14,29-31} As a result, more rigid chest wall reconstruction techniques, like mesh-methylmethacrylate sandwiches and rib replacement with spinal lubra plates, are probably unnecessary in dogs.

Wound problems are the most common complications after chest wall resection in dogs.^{6,7,14,15,18} Incisional seromas were noted early in the postoperative period in 5 dogs and all resolved spontaneously with conservative management. There was no significant difference in the incidence of seromas between autogenous, prosthetic, and composite reconstruction techniques. Incisional seromas are also the most commonly reported complication after chest wall resection and reconstruction in other canine studies, occurring in up to 40% of cases.^{6,7,15,18} Seromas are common because of the aggressive resection and the dead space created. We did not use subcutaneous Penrose drains, but this has been recommended to reduce the incidence of incisional seromas after mesh reconstruction of chest wall defects in dogs.^{7,8,18} Early wound infection or dehiscence did not occur in our dogs and are rare in other reports of chest wall reconstruction in dogs.^{3-6,14}

One dog reconstructed with a composite of Marlex mesh and latissimus dorsi muscle flap developed a deep infection at the incisional site 767 days after surgery. This was the only late surgical complication we encountered. This dog was eventually euthanatized because of recurrent deep-seated infection. In humans, infected meshes are managed by surgical removal and culture-directed antimicrobial therapy.¹³ Fibrous ingrowth into Marlex mesh results in a stable fibrous wall within 6 weeks^{32,34} and removal of the mesh does not compromise the integrity or strength of the reconstructed chest wall.¹³

The overall infection rate in these dogs was 2.3% and the infection rate associated with Marlex mesh reconstructions was 6.7%. This is similar to infection rates in studies of prosthetic reconstruction of chest wall defects in humans.^{12,22,24} Infection rates in other reports of chest wall reconstruction in dogs were <5%,^{3,5,6,17,18} but most follow-up times were short and mesh-associated infections frequently occur months to years after the surgical

procedure.²² Chest wall reconstruction with autogenous muscle flaps should be considered in dogs with primary rib CSA because prolonged survival is more likely in these cases.³⁻⁶ However, Bowman et al¹⁸ reported on Marlex mesh reconstruction of chest and abdominal wall defects in 20 dogs, with 6 of these dogs being followed for >17 months, and none of these dogs developed mesh-related infections. Furthermore, Marlex mesh is considered an ideal material for chest wall reconstruction partly because of its resistance to infection. In an experimental infected model where mesh was implanted into contaminated and noncontaminated wounds, healthy granulation tissue of uniform 3–4 mm thickness formed within 3 weeks in both groups and neither had evidence of bacterial infection.³² The infection rate associated with prosthetic meshes is decreased in both dogs and people after chest wall resection when the mesh is covered by well-vascularized tissue, such as pedicled or microvascular muscle flaps.^{10,11,13,18,22,39} Although the single late infection in the present series occurred in a dog with a composite Marlex mesh–latissimus dorsi muscle flap reconstruction, skin coverage alone over the mesh should be avoided as this may not provide sufficient blood supply to allow fibrovascular ingrowth into the mesh and subsequent stability and resistance to infection.

Postoperative pleural effusion was diagnosed in 3 dogs. One dog died of hemothorax secondary to disruption of the internal thoracic artery. Two dogs with serosanguineous pleural effusion both had partial sternectomies (4 and 6 sternebrae) reconstructed with Marlex mesh alone and both also developed peripheral edema. Pirkey-Ehrhart et al reported pleural effusion and peripheral edema in 5 dogs after chest wall resection but, unlike our dogs, pleural effusion and peripheral edema spontaneously resolved in these dogs without specific treatment.⁵ The pleural effusion in our dogs was most likely caused by irritation of the pleural surface of the lungs and heart on the exposed Marlex mesh, especially as contact between the mesh and intrathoracic organs is more likely after large sternal reconstructions. Furthermore, the diagnosis of peripheral edema in these dogs was probably incorrect as both dogs were normoalbuminemic. As previously noted, Marlex mesh is not impervious to fluids and the accumulation of large amounts of pleural fluid early in the postoperative period may have resulted in the flow of pleural fluid through the mesh into dependent subcutaneous spaces. In people, omental pedicle flaps are used to cover the pleural surface of the mesh to minimize mesh-induced pleuritis, by promoting local healing and enhancing neovascularity, and provide an airtight seal.⁹ Omental pedicle flaps were combined with Marlex mesh for chest wall reconstruction in 2 dogs in our series, and has also been reported in other studies,^{3,5,8} and neither dog experienced complications. To

minimize the risk of pleural effusion after chest wall reconstruction with prosthetic meshes, particularly sternal defects, the mesh should be covered with well-vascularized autogenous tissue, such as omental pedicle grafts on the pleural surface or muscle flaps on either the pleural or lateral surface of the mesh.

Complications were reported in 10% of autogenous reconstructions, 25% of composite reconstructions, and 67% of prosthetic reconstructions. Most of these complications were minor and required no or minimal treatment. There was no intraoperative mortality, but 4 dogs had major postoperative complications (hemothorax, unremitting pleural effusion, and late infection) resulting in eventual death or euthanasia. Complications were significantly more likely with prosthetic mesh reconstructions and reconstruction of sternal defects. When compared with autogenous chest wall reconstruction, the risk of complications were increased by 3- and 13-fold for composite and prosthetic chest wall reconstructions, respectively. Furthermore, for both prosthetic and sternal reconstructions, these complications were major and resulted in patient mortality. The significance of these findings may have been because of a type I statistical error, as there were only 3 dogs each with prosthetic reconstruction alone and sternal reconstructions, and 2 of these dogs had sternal defects reconstructed with Marlex mesh alone. Complications were not reported in the remaining dog with Marlex mesh reconstruction (3 ribs) or the dog with partial sternectomy (4 ribs and sternbrae) reconstructed with an autogenous latissimus dorsi muscle flap. Reconstruction of partial and total sternectomy defects presents specific challenges in humans and is also associated with a higher rate of complications compared with rib defects.^{9,12,22,24,37,40}

Autogenous muscle flaps alone may be sufficient for the reconstruction of sternal defects,^{10,27,37,40} and this was used successfully in 1 dog in our series. However, mesh-methylmethacrylate sandwiches are preferred by most surgeons for sternal reconstruction in people, particularly after total sternectomy, because this provides additional rigidity to the chest wall and protection of intrathoracic structures, and more closely mimics the anatomy and function of the normal sternum.^{9-13,41} Composite reconstructions, using mesh sandwiches containing either methylmethacrylate or corticocancellous bone, have been successfully used to reconstruct clinical and experimental sternal defects in a cat and a series of dogs.^{19,20} Based on our results, sternal defects should be reconstructed with autogenous muscle flaps and/or more rigid prosthetic techniques, like mesh-methylmethacrylate sandwiches.

Other controversial issues in chest wall resection in dogs include the number of ribs that can be safely resected and reconstructed and the impact of including the 1st rib in chest wall resections.⁶ In our series, 5 dogs had

the 1st rib resected (ribs 1–4 in 3 dogs and ribs 1–6 in 2 dogs) and 3 dogs had a maximum of 6 ribs resected. One dog with resection of 6 ribs and sternbrae, including the 1st rib, had postoperative complications and, as discussed earlier, this was most likely because of either the sternal resection or only prosthetic mesh was used to reconstruct the chest wall defect. Furthermore, the number of ribs resected did not significantly increase the risk of complications in this or other studies of chest wall resection in dogs.^{3,5} Hence, based on these findings, the 1st rib can be safely resected in dogs and up to 6 ribs can be safely reconstructed in dogs without an increased risk of ventilatory complications. Excision of rib tumors with complete histologic margins is the most important risk factor for local tumor recurrence and survival in both dogs and people,^{5,10} hence chest wall resection should not be compromised by either the location of the affected rib(s) or the number of ribs that require resection.

Addendum

We recently resected 3 ribs for excision of a primary rib CSA in a German Short-Haired Pointer and reconstructed the chest wall defect with a latissimus dorsi muscle flap. Postoperatively, the dog developed a seroma that did not resolve by 17 days. Ultrasonography and exploratory surgery were used to diagnose and treat partial necrosis of the distal aspect of the muscle flap. After debridement of the necrotic portion of the muscle flap and reconstruction of the resultant defect with prosthetic mesh, the seroma did not recur and the dog recovered uneventfully. As a result of this case and personal communication (D. White, 2008), partial or complete muscle flap failure should be considered as another cause of seroma after autogenous reconstruction of chest wall defects and this should be investigated if the seroma fails to spontaneously resolve within a reasonable time period.

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