The WHO uses the term MPNST to describe tumors that were previously known as malignant schwannoma, neurogenic sarcoma, and neurofibrosarcoma. These tumors are rare with an incidence of 0.001% in the general population and represent only 5% of malignant soft-tissue tumors. Malignant peripheral nerve sheath tumors primarily affect adults in the 3rd–6th decades of life. Approximately 50% of these tumors are associated with patients with neurofibromatosis Type I.

Malignant peripheral nerve sheath tumors are highly aggressive tumors and carry a poor prognosis. Overall 5- and 10-year survival rates are 34% and 23%, respectively. The 5-year survival rates have been reported to range from 34% to 52% with a median survival ranging from 44 to 66 months. Patients with paraspinal disease have a substantially worse prognosis, with 2- and 5-year survival rates of 35% and 16%, respectively, and a median survival of 8.5 months.

The best chance for long-term survival and possible cure is from complete resection. Multiple studies have shown improved survival from GTR. The decreased survival observed in those patients with spinal/paraspinal tumors has been attributed to an inability to obtain GTR. This is often difficult to achieve when the tumor spans several levels and involves multiple foramina and vascular structures. Furthermore, accessing the tumor requires extensive bone and soft-tissue removal, thereby severely destabilizing the spine.

Here, we present the case of a 14-year-old girl with an extensive thoracic spinal/paraspinal MPNST who had been previously treated with 2 subtotal resections and chemotherapy and radiation therapy, because of initial nonresectability. Following these interventions, there was...
partial tumor response, and then an aggressive surgical option (a staged 2-day procedure) was offered at our institution. We discuss the technique used to achieve GTR and how the patient’s myriad complications were managed. Ultimately, we used a multidisciplinary approach to treat her complications. She is now more than 6.5 years out from her initial diagnosis, 5 years out from her costotransversectomy, and 3 years out from her definitive fusion and bronchoscopy. The patient is neurologically intact, pain free, tumor free, infection free, has no evidence of a pseudarthrosis, and recently completed her 1st year of college on a full academic scholarship.

Case Report

History. This 14-year-old girl initially presented in October 2004 with thoracic back pain that progressed over the previous 4 months and was worse at night. The pain was localized under the lower margin of the left rib cage and radiated to the back. The pain woke her from sleep, and she had a weight loss of 9 lbs over 4 weeks. A CT scan showed a chest and paraspinal mass.

The patient’s examination showed normal power in her lower extremities and symmetrical brisk reflexes bilaterally at her knees. She also had numbness and severe pain over the left upper abdominal quadrant. An MR image revealed a left paraspinal mass with extension into the left neural foramina from T5–6 through T10–11 (Fig. 1). There was no evidence of bone erosion or spinal cord compression.

The patient underwent a thoracoscopic biopsy of the mass. Based on initial biopsy findings, the mass was thought to be plexiform neurofibroma. The initial neurosurgical opinion was that the paraspinal mass was unresectable. Ten days later, the patient underwent a left thoracotomy for tumor debulking. There was reported extensive hemorrhage with that surgery that precluded further debulking, and final pathology revealed malignant disease. This situation may occur in either transforming plexiform neurofibromas or from selection bias in limited biopsies. Final pathology revealed an extensive high-grade MPNST with a Ki 67 of 50%. There were areas of tumor compatible with plexiform neurofibroma, making transformation the likely etiology.

The residual tumor was treated with involved field radiation over the next 2 months (November 2004–January 2005). The patient initially was treated with anteroposterior/posteroanterior fields to the left paraspinal region covering T6–10 with a dose of 1800 cGy. This was followed by an 8-field intensity-modulated radiation therapy plan to a dose of 4860 cGy. Her total tumor dose was 6600 cGy in 37 fractions over 56 days. One month following her radiation therapy, MR imaging revealed a slight interval increase in total size of the tumor but with significant areas of necrosis compatible with radiation effect.

The patient began chemotherapy in February 2005. She received a modification of the recent MPNST pilot treatment trial (COG-ARST0332) because of her prior thoracic spinal radiation therapy. She received etoposide and ifosfamide initially alternating with vincristine, doxorubicin, and cyclophosphamide, and then with substitution of actinomycin for doxorubicin (total doxorubicin 225 mg/m²). There was ongoing evidence of small decrements in tumor size and/or increase in areas of necrosis. A second left thoracotomy was performed in September 2005 to further debulk the tumor mass. Pathological findings showed significant treatment effect with an approximate residual of viable tumor in the specimens of 25%, so she resumed chemotherapy. By April 2006, there was minimal to no further reduction in tumor size with chemotherapy, and the patient and her parents were given the options of palliation without further interventions for cancer focusing on quality of life, palliation with palliative chemotherapy, or an extensive resection and fusion. They opted for the surgery, and she was referred to the senior author (P.B.S.).

Operation

Day 1. The patient was taken to the operating room, intubated with a double-lumen tube, and positioned on a Jackson table in the straight prone position. Somatosensory evoked potentials and motor evoked potentials were monitored. A midline incision was made from C-5 to L-2. The soft tissue was only removed from the left lamina, transverse processes of T1–12, and the 3rd–12th ribs to center the exposure over the left chest wall. The left lung was selectively deflated. Using a rib cutter, the 4th–10th ribs were removed and placed in a subcutaneous pocket and on Day 2 were morcellized and laid down on the contralateral gutter as bone graft. The underlying intercostal muscles were adherent to the lung but were

Fig. 1. Axial T1-weighted MR images obtained after contrast administration. Upper: Preoperative image showing the MPNST extending through the neural foramen and abutting the spinal cord, vertebral body, and aorta. Lower: Postoperative image showing GTR of the tumor.
removed using Bovie cautery. Because the left lung was not being ventilated, there was excellent exposure of the tumor along the aorta and vertebral bodies. On the left the lamina, facets and transverse processes from T-4 to T-10 were removed. All that remained of the posterior elements on the left were the pedicles.

Starting at the T-10 level, the left segmental artery was dissected out from the encasing tumor, and a temporary aneurysm clip was placed on the segmental artery at its origin from the aorta. This was performed at each level from T-10 to T-4. Spinal cord monitoring signals remained stable. Each aneurysm clip was removed, and a 2-0 silk was used to tie off the vessel. After all of the segmental arteries were cut, the nerve roots from T-4 to T-10 were similarly tied off and sectioned. This allowed a large portion of tumor to be removed with nerve roots and arteries. The small areas of tumor that remained on the aorta and vertebral bodies were removed piecemeal until GTR was obtained (Fig. 2). The patient was taken to the pediatric intensive care unit and remained intubated overnight for the procedure the following day.

Day 2. The patient underwent MR imaging prior to returning to the operating room to rule out residual tumor before hardware was placed. Magnetic resonance imaging showed GTR (Fig. 1). The patient underwent stabilization with a T1–12 pedicle screw and rod construct (Click’X, Synthes). Once the instrumentation was in place, the plastic surgery team was called on to assist in reconstructing the posterior chest wall using Marlex mesh and methylmethacrylate (Fig. 2). Because of the previous thoracotomies, a rotational muscle flap was not possible.

The patient initially recovered well and was out of bed on postoperative Day 2. However, on postoperative Day 6, she developed an infection requiring the removal of the methylmethacrylate and the bone graft and a washout with copious irrigation. She returned to the operating room for 2 more washouts over the next 7 days, but the hardware was not removed. The infection cleared, and her thoracoplasty healed without further surgical intervention.

**Management of Bronchocutaneous Fistula and Kyphoscoliosis.** Over the next 21 months, the patient had recurring upper respiratory infections, pleural effusions, and pneumonias due to her poorly healing irradiated lung and overlying skin tissue. These repeated pulmonary infections caused skin breakdown, and the screw heads were eroding through her skin. She developed a broncho-cutaneous fistula along her incision line with a persistent air leak (Fig. 3). She had bronchopleural-cutaneous and bronchopleural-dural fistulas with intermittent pneumocephalus with coughing, causing intense headaches. The patient returned to the operating room for removal of her instrumentation and latissimus dorsi free-flap reconstruction performed by the plastic surgery team. She was discharged home with 2 Jackson-Pratt drains, and she continued taking antibiotics.

The patient returned 3 weeks later because she had lost 2.5 inches of height and her drains would not hold suction due to a large air leak. Standing scoliosis radiographs demonstrated significant deformity from a pseudarthrosis (Fig. 4). She was taken back to the operating room for revision of the latissimus dorsi free flap, implantation of a vascularized fibular graft, and instrumented fusion with monoaxial pedicle screws and rods (Synthes USS). The spine was exposed, and larger diameter screws were reinserted from T-2 to L-2, with excellent correction of her
deformity. The skin overlying the latissimus dorsi flap was now well vascularized, and the latissimus dorsi was repositioned over the surface of the lung to prevent further air leaks. Fibula was harvested along with its vascular supply from her right leg and the saphenous vein from her left lower extremity. After decortication, the fibula was placed along the transverse processes and rib angle intersection from T-4 to T-10. The saphenous vein connected the fibular vascular pedicle with axillary vessels (Fig. 5). The patient tolerated the procedure well, and on postoperative Day 3 she underwent a flexible bronchoscopy performed by the interventional pulmonology service for placement of novel endobronchial one-way valves (IBV Valves, Spiration, Inc.) under the Food and Drug Administration/institutional review board–approved compassionate use protocol. Two valves were placed in the supine position, and the air leak initially stopped. However, once the patient was placed in a seated position, her drains again lost suction requiring the placement of 4 more valves to ultimately close off the leak. She received a total of 6 valves, 5 in her left lower lobe, and 1 in her left upper lobe.

Postoperative Course. The patient is now 3 years removed from her last procedure and has not had any complications or complaints since her last surgery. Her incision is well healed (Fig. 6), she has no evidence of a pseudarthrosis (Fig. 7), and she has returned to her previously active lifestyle.

Discussion

Malignant peripheral nerve sheath tumors are rare tumors with an incidence of 0.001%. They have a poor prognosis, and complete resection is the only known curative treatment.12 Paraspinal MPNSTs have a worse prognosis because they often involve multiple spinal levels and crucial vascular structures, as was the case in the patient presented here. Given the dismal outcome, we recommend that paraspinal MPNSTs be completely resected even if the surgery requires an aggressive approach that severely destabilizes the spine in a patient who has received prior radiation.

A paraspinal mass in the pediatric population should be initially biopsied prior to an aggressive resection. Tumors such as Ewing sarcoma, lymphoma, neuroblastoma, Langerhans cell histiocytosis, ganglioneuroma, and ganglioneuroblastoma are managed medically. However, the first line of therapy for tumors such as chordomas, MPNSTs, or atypical teratoid rhabdoid tumors is a GTR.

This patient was not referred to us until after she had received radiation therapy and chemotherapy. Without outstanding multidisciplinary support from the plastic surgery and pulmonary services, the complications would have likely made the resection unsuccessful.

The original resection was staged because we wanted to obtain a high-quality thoracic MR image without the hardware artifact after we removed the tumor. We were fortunate that the patient did not lose somatosensory evoked potentials and motor evoked potentials when we placed the...
temporary aneurysm clips. If her signals had decreased below 50%, we would have removed the clips from the arteries responsible for the changes and stripped the tumor off of the aorta and segmental artery. We have performed this technique with cervical chordomas, MPNSTs, and atypical teratoid rhabdoid tumors off of the vertebral artery, with tumor-free follow-up of 7, 4, and 2 years, respectively. En bloc resection is ideal, but it should be balanced with the risk of paraplegia or quadriplegia, especially in a tumor that has a high likelihood of recurrence.

The most problematic complication was the continued air leak due to nonhealing lung tissue. The continued infections would have made any type of fusion, even a vascularized fibular graft, difficult if not impossible. We knew that the lung needed to be addressed, but members of the thoracic surgery and interventional pulmonary services believed that any intervention was too dangerous. Fortunately, recently developed one-way endobronchial valves were being implanted bronchoscopically in adults with emphysema. The valves allow passage of air out of distal lung segments, but block airflow into the targeted airways. We were able to get a compassionate use exemption from the Food and Drug Administration for the IBV Valves for the bronchial fistulas in our patient. The portion of lung that was blocked was not involved in gas exchange because of the radiation-induced atelectasis. Therefore, valve placement had no deleterious effect on the patient’s pulmonary function. The important technical note is that when the patient was flat and supine, her drains held suction, suggesting that all of the air leaks were treated. However, when we inclined the bed, the drains began losing suction and more valves had to be placed. This maneuver saved the patient an additional procedure. The valves in combination with the latissimus dorsi flap and long-term antibiotic therapy eliminated her air leak and pulmonary infections. Other than incisions on her lower extremities, she has no morbidity related to her fibular or saphenous grafts.

The patient is now 6.5 years removed from her initial diagnosis and 3 years removed from her definitive surgery. In the presence of radiation therapy, repeated postoperative infections, and a bronchocutaneous fistula, she has no hardware failure and remains tumor free. Furthermore, she is neurologically intact, pain free, has not had any major respiratory infections, has a well-healed incision, and recently completed her 1st year of college.

Conclusions

A multidisciplinary approach using novel endobronchial valves, a latissimus dorsi free flap, and a vascularized fibular graft is safe and effective in treating a pseudarthrosis and air leak from nonhealing irradiated lung, bone, and soft tissue after an aggressive T4–10 costotransversectomy for a paraspinal MPNST. We advocate a multidisciplinary approach because of the high morbidity associated with these procedures. We now use a vascularized fibular graft at the time of the original fusion when patients are referred to us after they have received prior radiation therapy and require extensive bony removal. As spinal instrumentation becomes more sophisticated and biological technology for augmenting fusions improves, radical resections and fusions will be possible with fewer complications.

Disclosure

Dr. Sterman has served as a scientific and regulatory consultant.
for Spiration, Inc., the manufacturers of the IBV Valve, and the sponsor of the pivotal trial of use of the IBV Valve for advanced emphysema.

Author contributions to the study include the following. Conception and design: Heuer, Whitmore, Birknes, Belasco, Sterman, Low, Storm. Acquisition of data: all authors. Analysis and interpretation of data: McLaughlin, Low, Storm. Drafting the article: McLaughlin. Critically revising the article: McLaughlin, Whitmore, Birknes, Belasco, Sterman, Storm. Reviewed final version of the manuscript and approved it for submission: all authors. Study supervision: Storm.

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