Schwannomas are benign soft-tissue tumors that arise from peripheral nerve sheaths throughout the body and are commonly encountered in patients with neurofibromatosis Type 2. The vast majority of schwannomas are benign, with rare cases of malignant transformation reported. In this pictorial review, we discuss the magnetic resonance imaging (MRI) appearance of schwannomas by demonstrating a collection of tumors from different parts of the body that exhibit similar MRI characteristics. We review strategies to distinguish schwannomas from malignant soft-tissue tumors while exploring the anatomic and histologic origins of these tumors to discuss how this correlates with their imaging findings. Familiarity with the MRI appearance of schwannomas can help aid in the differential diagnosis of soft-tissue masses, especially in unexpected locations.

**KEYWORDS:** Magnetic resonance imaging, malignant peripheral nerve sheath tumor, peripheral nerve sheath tumor, schwannoma

Schwannomas, sometimes referred to as neurilemmomas, are benign peripheral nerve sheath tumors that occur anywhere in the body and represent approximately 5% of all soft-tissue tumors. While the majority of cases occur sporadically, cases may be seen in association with genetic disorders such as neurofibromatosis (NF) Type 2 or, more rarely, Type 1. Schwannomas are composed of Schwann cells that normally produce myelin sheath covering the peripheral nerve. Schwannomas are further classified into two types based on distinct histological patterns – Antoni A and B types. Type 1 is highly cellular and demonstrates nuclear palisading and Verocay bodies. Verocay bodies refer to a stacked arrangement of two rows of elongated palisading nuclei and alternating bands of acellular zones that are made up of tubular cytoplasmic processes of Schwann cells. Type 2 has more loosely organized cellular structure with areas of myxomatous and cystic changes. It is often thought that Type 2 represents degenerated Type 1 tissue. The tumors develop as fusiform masses eccentrically located with the involved nerve and are contained within the epineurium.

The typical magnetic resonance (MR) appearance is iso-to-hyperintense (compared to muscle) on T1-weighted images, hyperintense on fluid-sensitive sequences, and often diffusely enhancing on contrast-enhanced images.[1] Tissue heterogeneity is relatively common, particularly cystic degeneration. When present,
heterogeneity has been shown to correlate histologically with a greater ratio of Antoni B tissue than Antoni A. On MR imaging (MRI), Type 1 predominant tumors tend to be small and homogeneous while heterogeneous tumors (with or without cystic degeneration) tend to have higher proportions of Type 2. Larger and more heterogeneous tumors also demonstrate increased hemosiderin deposits and may be referred to ancient schwannomas.\(^2,3\) Malignant degeneration of schwannomas is exceedingly rare.

In this pictorial review, we present a spectrum of schwannomas that arise in peripheral nerves in different regions of the body from head to toe. The illustrative cases were collected from two institutions (National University Hospital, Singapore and Mayo Clinic, Rochester, MN, USA) from January 2003 to December 2015. All cases are pathology proven, except for those patients with multiple schwannomas when an earlier excised tumor was pathology-proven schwannaoma.

**HEAD AND NECK SCHWANNOMAS**

Approximately 45% all schwannomas occur in the head and neck region arising from peripheral, cranial, or autonomic nerves \(^1\). Clinical symptoms typically correlate with distribution of the involved nerve though this may be confounded by size and location of the mass. The vestibulocochlear nerve is most commonly involved, accounting for 6%–8% of all intracranial tumors and 80% of cerebellopontine angle tumors. Bilateral vestibular schwannomas are commonly seen in NF Type 2. In the rare cases of malignant nerve sheath tumors, approximately 20% occur in the head and neck. Poor prognostic factors include tumor (size >5 cm), presence of NF, and incomplete resection.\(^4\)

**Spinal schwannomas**

Schwannomas and neurofibromas represent 25%–30% of intraspinal masses. They may be intradural (70%–75%), extradural (15%), or combined intradural/extradural (15%), referred to as a dumbbell tumor.\(^5\) Clinical presentation varies depending on the site of involvement, but pain and paresthesias are the most commonly reported symptoms [Figures 7-10].

**INTRA-ABDOMINAL SCHWANNOMAS**

Intra-abdominal schwannomas [Figures 11 and 12] are uncommon, with the stomach being the most frequent site. Colorectal and retroperitoneal schwannomas are very rare. Diagnosis is difficult preoperatively and usually requires surgical excision. These tumors are often discovered incidentally on imaging but may present with nonspecific symptoms depending on location and size. On imaging, intra-abdominal schwannomas may be very difficult to differentiate between the more common gastrointestinal mesenchymal tumors (i.e., leiomyoma, leiomyosarcoma, and gastrointestinal stromal tumor [GIST]).\(^6\)

**THORACIC SCHWANNOMAS**

Intrathoracic schwannomas can arise from any thoracic nerve, but they are most often found in the middle or posterior mediastinal compartments. Most commonly they arise from a spinal nerve root, intercostal nerve [Figure 13], or the brachial plexus and extend into the thoracic cavity. Schwannomas arising from the vagus and recurrent laryngeal nerves have also been reported. MRI is essential before surgical intervention to evaluate for intraspinal extension because the operative approach may differ. In 50% of cases, erosion/deformity

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**Figure 1:** Contrast-enhanced brain magnetic resonance imaging in a patient with clinical diagnosis of neurofibromatosis Type 2. (a) Axial T2-weighted sequence demonstrates small bilateral isointense vestibular masses (arrows). (b) Enhanced T1-weighted sequence demonstrates enhancement of the masses. Right-sided mass is larger, causing mild expansion of the internal acoustic canal and an “ice-cream cone” appearance. Bilateral vestibular schwannomas are most commonly seen in patients with neurofibromatosis Type 2.

**Figure 2:** Contrast-enhanced brain magnetic resonance imaging. (a) Axial T2-weighted sequence demonstrates a right vestibular mass with high T2 signal correlating with areas of cystic degeneration (arrow). (b) Enhanced T1-weighted sequence demonstrates mild heterogeneous enhancement of the solid portions of the mass, with low T1 signal correlating with the cystic component (arrow).
Extremity schwannomas

Schwannomas are the most common solitary tumor of the peripheral nerve [Figures 14-19]. They typically present as a slow-growing firm round mass with paresthesias of the associated nerve distribution. In the upper extremities, flexor surface is the most common location of ribs, vertebral bodies, and neural foramina can be seen. They are typically round and firm masses, with a slow growth rate and no tendency towards spontaneous regression. The slow-growing, firm mass of a schwannoma can lead to symptoms due to compression of the nerve, such as pain, paresthesias, and weakness. Imaging studies can help identify schwannomas, with MRI being the gold standard due to its ability to demonstrate the exact location and extent of the tumor. This is especially important in extremity schwannomas, where accurate localization is crucial for surgical planning and management.
location due to the presence of large nerves. Due to their eccentric location, these tumors can often be excised with preservation of nerve function.

**DISCUSSION**

Schwannomas demonstrate typical MRI features of T1 iso-to-hypointensity, T2 hyperintensity, and postcontrast enhancement. Heterogeneous signal intensity and postcontrast enhancement are suggestive of internal hemorrhage and myxoid/cystic changes. There are additional imaging and pathological features which suggest the diagnosis of schwannomas; however, they are not specific for schwannomas.
and also may be present in other neurogenic tumors including neurofibromas and malignant peripheral nerve sheath tumors. The entering and exiting nerve sign describes the presence of a peripheral nerve coursing in and out of the mass.\textsuperscript{[1]} This can be seen on pathological analysis and may or may not be seen on imaging depending on the size of the mass. The target sign consists of low/intermediate T2 signal centrally (fibrous tissue), with high T2 signal peripherally (myxoid tissue).\textsuperscript{[1]} The fascicular sign represents multiple ring-like structures, corresponding to fascicular bundles also seen in cross section of normal nerves.\textsuperscript{[1]} A secondary sign that may suggest a neurogenic neoplasm is muscle atrophy within the nerve distribution.\textsuperscript{[1]}

**Conclusion**

While common MRI characteristics for schwannomas exist, diagnosis by imaging alone remains challenging. Recognizing described imaging patterns for schwannomas can help narrow down a differential diagnosis of soft-tissue masses, especially in unexpected locations.
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