ABSTRACT
Objective: To present a new concept of surgical procedure for total removal of cervical schwannomas with neural function preservation, and the outcomes of this procedure in a series of tumors with special reference to post-operative function of the nerve of origin.
Method: A retrospective case study of consecutive 19 cases seen from Jan. 2003 to April 2008 who underwent inter-capsular resection of cervical schwannomas derived from the nerve of vagus, hypoglossus, sympathetic trunk, accessorius etc. was performed. During the procedure, motor fibers were located on the surface of the tumor using nerve stimulator. Avoiding motor fibers, nerve sheath(epineurium and perineurium) is cut with a scalpel and the true capsule of the tumor is identified. By the dissection between nerve sheath and true capsule, tumor is completely removed. The senior author named this procedure “Inter-capsular resection”.
Result: All tumors were resected completely, which was proven by pathological study. No motor function deficit was resulted in except a case of vagus nerve origin, and mild Horner’s sign was experienced in a case with the tumor of superior cervical ganglion origin. In a case of cervical plexus schwannoma, nerve fibers were seen in the tumor pathologically.
Conclusion: Cervical schwannoma can be totally removed without post-operative motor function deficit by inter-capsular resection in the majority of the cases.

1. Introduction
Cervical schwannomas may derive from any of cranial nerves, peripheral nerves or autonomic nerves in the neck. To date, these tumors have been often removed by sacrificing the nerve of origin without trying to preserve neural function[1]. Even though in cases with attempt of preserving nerves, neural function was not preserved in many cases[2] and the patients have been suffering from neural deficit. In order to resolve this problem, the senior author has developed a new surgical procedure to remove only the tumor while preserving the nerve of origin, and named it “Inter-capsular resection (ICR)”[3]. In this paper, a concept and surgical technique of this procedure is presented and the result of a series of cases is reported.

2. Histopathology of schwannoma
The peripheral nerve consists of many nerve fibers including myelinated and unmyelinated fibers. A myelinated fiber consists of an axon and surrounding myelin sheath, which is Schwann cell. A myelinated nerve fiber is covered by thin fibrous membrane called endoneurium and many of such fibers gather to form fascicles. These fascicles are covered by perineurium and further gather to form a nerve. A nerve is finally covered by strong fibrous membrane called epineurium or nerve sheath[4]. Because schwannoma is the tumor of a Schwann cell, it is certain that schwannoma is covered by endoneurium and further covered by perineurium and finally by epineurium together with other thousands of nerve fibers. Thus, grew up schwannoma is surrounded by numerous intact nerve fibers and covered by epineurium. Usually, intact nerve fibers are located at a side forming a fascicle on the surface of the tumor(Fig.2).

3. Concept of Inter-capsular resection
The key points of inter-capuslar resection are;
1) The epineurium(nerve sheath) and perineurium is cut longitudinally by true scalp kel and the true tumor capsule, on which tumor vessels are seen, is identified. The layer just above the true tumor capsule is dissected to remove the tumor covered by thin fibrous capsule containing vessels(Fig.3).
2) Cut line of the epineurium should be set at the opposite side of normal nerve fascicle when it is recognized, or at the area where no motor response is seen by a nerve stimulator.

The first point means that the dissection is made between the true tumor capsule and surrounding normal neural structure(pseudo-capsule)such as nerve fibers, epineurium and so on. This is an etymology of “Inter-capsular resection”. The second point is to avoid damaging and/or transecting motor fibers when epineurium is cut.

4. Result
From January 2003 to April 2008, consecutive 19 cases have been operated on by the senior author and colleagues(Table 1). In 18 cases, the nerve of origin was anatomically well preserved but in 1 case of vagus nerve origin, it was impossible to preserve the nerve because the trunk of the nerve obviously showed tumorous change(Fig.8). In another case derived from superior cervical ganglion, some ganglion cells were removed together with true tumor although sympathetic trunk was preserved.

In other 17 cases (89%) the nerve of origin and its function was preserved regardless of tumor size. Total removal was confirmed by pathological examination (Fig.7).

5. Discussion
It is not difficult to remove a schwannoma totally if the nerve of origin is sacrificed with the tumor. However, every single nerve in the human body has its own function and it is desirable to preserve the function in any situation. As described above, whole tumor contains fascicles of normal nerve fibers and true tumor, and if only the true tumor is resected from normal fascicles and epineurium, neural function preservation would be achieved.

For this purpose, only the tumor parenchyma has been removed by cutting the true tumor capsule in many cases. This technique is called “enucleation” but tumor cells are left behind inside the tumor capsule, which may result in recurrence. Thus, enucleation does not mean “total removal”. By inter-capsular resection, the tumor covered with tumor capsule is totally resected (Fig.7).

However, even by this technique, it may be impossible to preserve the nerve of origin when the nerve trunk itself shows tumor transformation or is encased in the tumor.

6. Conclusion
Cervical schwannoma can be totally removed without post-operative neural function deficit by inter-capsular resection in the majority of the cases.

References