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Increasing Incidence of Degenerative Spinal Diseases in Japan during 25 Years: The Registration System of Spinal Surgery in Tohoku University Spine Society

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Spinal disorders affect mainly older people and cause pain, paralysis and/or deformities of the trunk and/or extremities, which could eventually disturb locomotive functions. For ensuring safe and high-quality treatment of spinal disorders, in 1987, the Tohoku University Spine Society (TUSS) was established by orthopedic departments in Tohoku University School of Medicine and its affiliated hospitals in and around Miyagi Prefecture. All spine surgeries have been enrolled in the TUSS Spine Registry since 1988. Using the data from this registration system between 1988 and 2012, we demonstrate here the longitudinal changes in surgical trends for spinal disorders in Japan that has rushed into the most advanced "aging society" in the world. In total, data on 56,744 surgeries were retrieved. The number of spinal surgeries has annually increased approximately 4-fold. There was a particular increase among patients aged ≥ 70 years and those aged ≥ 80 years, with a 20- to 90-fold increase. Nearly 90% of the spinal operations were performed for degenerative disorders, with their number increasing approximately 5-fold from 705 to 3,448. The most common disease for surgery was lumbar spinal stenosis (LSS) (35.9%), followed by lumbar disc herniation (27.7%) and cervical myelopathy (19.8%). In 2012, approximately half of the patients with LSS and cervical myelopathy were ≥ 70 years of age. In conclusion, the number of spinal operations markedly increased during the 25-year period, particularly among older patients. As Japan has a notably aged population, the present study could provide a near-future model for countries with aging population.

Keywords: aging society; longitudinal study; registry; spine; surgery
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Introduction

A county is defined as "aging society," "aged society" and "super-aged society" when elderly citizens aged ≥ 65 years exceeds 7%, 14% and 20% of its total population, respectively (Florence 2009). Japan became an "aging society" in 1970, which was about 50-100 years later than France in 1864 and Italy in 1927, and went into an "aged society" in 1994 following Germany in 1972, France in 1979 and Italy in 1988. Japan, however, rushed into a "super-aged society" in 2006, earliest in the world (Florence 2009). Now, Japan is the most advanced "aging society" in the world. In line with aging of the population, its family structures have been greatly changed. The numbers of total households with at least one-person aged ≥ 65 years was 6.3% in 1986 and markedly increased to 24.2% in 2014. Among them, inhabitants living with spouse only or living alone in 1986 and 2014 was 32.1% and 55.4%, respectively

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(website from Ministry of Health, Labour and Welfare of Japan, http://www.mhlw.go.jp/toukei/saikin/hw/k-tyosa/k-tyosa14/dl/02.pdf). Those rapid changes of population composition and family structures in this half-century in Japan may be an epitome of future in the developed countries or rapid developing countries. In such situation, people have become more sensitive to active aging and healthy life years. Spinal disorders cause pain, paralysis and/or deformities of the trunk and/or extremities, which disturb locomotive functions. Those diseases affect mainly older people. Therefore, the number of spinal surgeries has been increasing year by year (Tanaka et al. 2003). However, the longitudinal changes in trends of spinal surgery with a large number of patients and with longer history have not been clarified.

In 1987, the Tohoku University Spine Society (TUSS) was established by orthopedic departments in Tohoku University School of Medicine and its affiliated hospitals in and around Miyagi Prefecture, a province in northeastern Japan. All spine surgeries have been enrolled in the TUSS Spine Registry since 1988. This is the oldest and largest spine surgery registration system in Japan and is supposed to cover about 4 million inhabitants. Using the data from this system, we have reported several epidemiological studies in Japanese and English journals (Kokubun et al. 1996; Sato et al. 1998; Tanaka et al. 2003; Aizawa et al. 2006, 2012a, b, 2015). In addition to introduce the TUSS Spine Registry, the purpose of the present study was to clarify the changes of surgical trends by analyzing registered cases over the period of a quarter century through 2012.

Materials and Methods

The study protocol was approved by the Ethics Committee of Tohoku University School of Medicine (2011-304). The TUSS Spine Registry has collected the following data regarding all the patients who underwent spinal surgery at the orthopedic departments in Tohoku University School of Medicine and its affiliated hospitals: name, age, sex, residential prefecture, date of the surgery, name of hospital, spinal level, pathology, and surgical procedure.

Spinal pathologies were categorized into 19: (1) myelopathy (neurologic deficit related to spinal cord), (2) radiculopathy (neurologic deficit related to nerve root), (3) lumbar disc herniation (LDH), (4) lumbar spinal stenosis (LSS), (5) lumbar degenerative spondylolisthesis, (6) lumbar spondylolysis, (7) lumbar spondylolytic spondylolisthesis, (8) idiopathic scoliosis, (9) degenerative spinal deformity, (10) pyogenic spondylitis, (11) tuberculous spondylitis, (12) spinal cord tumor, (13) primary spinal tumor, (14) metastatic spinal tumor, (15) spinal trauma, (16) spinal lesion in rheumatoid arthritis such as atlanto-axial subluxation, (17) congenital spinal disorders such as congenital scoliosis, (18) destructive spondyloarthropathy related to long-term hemodialysis and (19) others. Surgical procedures were also grouped into 17: (1) anterior spinal fusion, (2) laminoplasty for myelopathy, (3) foraminotomy for radiculopathy, (4) laminectomy, (5) discectomy through partial hemilaminectomy for LDH first described by Love and Walsh in 1940, (6) lumbar fenestration (partial laminectomy with partial facetectomy), (7) lumbar lateral fenestration for nerve root compression in the lateral foramen, (8) posterolateral lumbar fusion (PLF), (9) endoscopic surgery for LDH or LSS, (10) spinal cord tumor removal, (11) curettage for infectious spondylitis or spinal tumor, (12) open biopsy, (13) anterior instrumented spinal fusion, (14) posterior instrumented spinal fusion, (15) posterior lumbar interbody fusion (PLIF) which means a posterior approach, removal of the intervertebral disc and replacement to bone or cage, and spinal fusion using pedicle screw and rod system, (16) instrumented spinal fusion through combined anterior and posterior approach, and (17) others.

This study used the data during 25 years from 1988 to 2012 and assessed the annual changes in the number of spine surgeries from the view points of age and sex distributions, pathologies, and analyzed surgical procedures for common spinal disorders. The number of hospitals which participated in TUSS Spine Registry was 28 in 1988. It had increased to 35 as of 2012: 22 in Miyagi Prefecture, 4 each in Iwate and Yamagata Prefectures, 2 each in Akita and Fukushima Prefectures, and 1 in Ibaraki Prefecture.

Results

In total, data on 56,744 surgeries were retrieved. The male/female ratio of the patients was 1.57 (34,629/22,115). The annual numbers of spine surgeries are shown in Fig. 1. The number for the whole patients was 892 in 1988 and climbed year after year except for a reduced number in 2011, the year of the Great East Japan Earthquake, as that for male patients. The number reached 3,807, a 4.3-fold larger number, as of 2012.

The age distributions of the whole, male and female patients are shown in Fig. 2A. The most common generation was the 8th decade among the whole and female patients, while it was the 7th decade among the male patients. The annual numbers of surgeries in each generation are shown in Fig. 2B. The number of surgeries for patients $\geq$ 60 years and those of < 20 years showed remarkable contrast. The former markedly increased after around 2000, while the latter showed almost same numbers fewer than 100 during the 25 years. The most common generation was the 6th or 7th decade showing nearly the same number in the beginning. It was the 7th decade between 1994 and 2001 and shifted to the 8th decade thereafter. Compared with their respective numbers in 1988, the 7th, 8th decades and patients $\geq$ 80 years demonstrated approximately 5-fold, 18-fold and 60-fold increases, as of 2012.

The most common spinal levels for surgery was the lumbar spine accounting for 67.4%, followed by the cervical spine for 26.1%, the thoracic spine for 6.0% and the sacrum for 0.5%. The annual rate of surgeries little fluctuated at every spinal level during the 25-year study period (Fig. 3). The most common major category of clinical diagnosis was degenerative spine accounting for 87.5% followed by trauma accounting for 4.8%, tumor accounting for 3.9%, idiopathic/congenital spinal disorders accounting for 1.1%, infection accounting for 0.8% and others (Table 1). The annual numbers of surgeries for degenerative spinal disorders and trauma increased approximately 5-fold and 3-fold, respectively, during the study period. On the other hands, those for other categories indicated almost steady

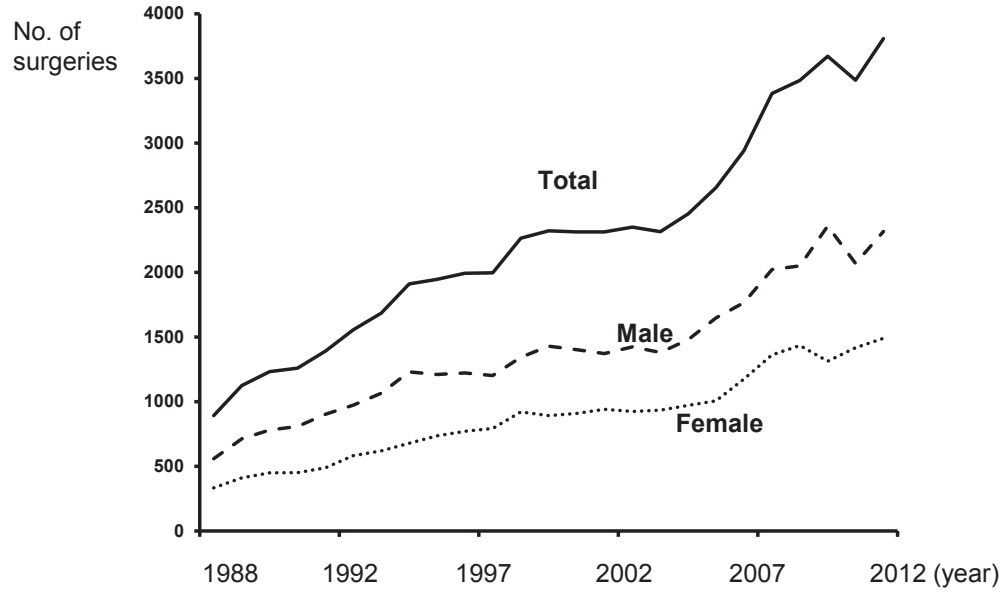

Fig. 1. Annual numbers of spine surgeries in Tohoku University Spine Society.
The number of spine surgeries was 892 in total (male/female = 559/333) in 1988, which gradually increased year by year with 1,994 (1,222/772) in 1997, 2,941 (1,768/1,173) in 2007, and 3,807 (2,318/1,489) in 2012.

numbers (Fig. 4).

Among degenerative spinal disorders, LSS including degenerative spondylolisthesis, LDH and cervical myelopathy were the three most common accounting for 35.9%, 27.7%, and 19.8%, respectively and totaled 83.4% of the whole surgeries during the 25 years (Table 1). The annual number of surgeries for LSS increased approximately 10-fold, and those for LDH and cervical myelopathy increased approximately 3-fold each during the period. LDH was the most common in the beginning but after reaching a peak in 1994, it was overtaken by LSS in 1996. LSS increased steadily till 2005 and acutely thereafter. As a consequence, its annual number was more than double as many as that of LDH in the last year of the study period. Cervical myelopathy steadily increased till 2003 but stayed in a plateau thereafter (Fig. 5).

Focusing on the patients aged ≥ 70 years, LSS, LDH and cervical myelopathy accounted for 46.2%, 8.0% and 32.7%, respectively, of all patients with each spinal disorder, and those older patients totaled 28.9% of the whole spine surgeries for the 25 years. Their annual numbers increased approximately 35-, 30- and 11-fold, respectively, during the period. Cervical myelopathy was the second most common diagnosis for surgery following LSS among the patients ≥ 70 years although LDH showed a higher increase rate than cervical myelopathy (Fig. 6A). Approximately half of the patients who underwent surgery for LSS or cervical myelopathy in the last year of the study period were aged ≥ 70 year (Fig. 6B).

The annual changes in the numbers of surgical procedures performed for the three most common spinal disorders are shown in Fig. 7A-C. As for cervical myelopathy, laminoplasty and anterior decompression and spinal fusion (ASF) covered almost all patients and shared them half and half in the first 5 years (Kokubun et al. 1996; Kokubun and Sato 1998). The number of surgeries of laminoplasty indicated approximately 5-fold increase during 25 years while that of ASF showed a reduction by half (Fig. 7A). As for LSS, fenestration every year covered approximately 75% to 85% of all surgeries. Instrumentation was first combined in 1989, and its usage had increased to 6% of all surgeries for the disorder as of 2012. Laminectomy has been also slightly increasing recently to approximately 10% to 15% of all surgeries (Fig. 7B). Discectomy through partial hemilaminectomy by Love and Walsh (1940) was only procedure for all LDH till 2001, except relapsed disc, huge central disc causing cauda equina syndrome, intradural extrusion and intra- or extra-foraminal herniation, which were removed through laminectomy or lateral fenestration and were designated as "others" in Fig. 7C. Microendoscopic discectomy (MED) was introduced in our area in 2002 and the number of surgeries by it increased year by year (Foley and Smith 1997). MED covered more than 20% of all patients with LDH in 2012.

Discussion

Nation-wide spinal surgery registry

Several nation-wide registration systems for spinal surgery have been established in Sweden (Swespine) (Strömqvist and Jönsson 1993; Jansson et al. 2003, 2004, 2005; Öhrn et al. 2011; Strömqvist et al. 2013; Fritzell et al. 2015), in Norway (NORspine) (Solberg et al. 2013; Fredø et al. 2014; Grotle et al. 2014), in Switzerland (SWISSspine) (Schluessmann et al. 2009; Aghayev et al. 2012; Hübschle et al. 2014), in Turkey (Utku et al. 2010) and United Kingdom (Breakwell et al. 2015). Except Swespine since

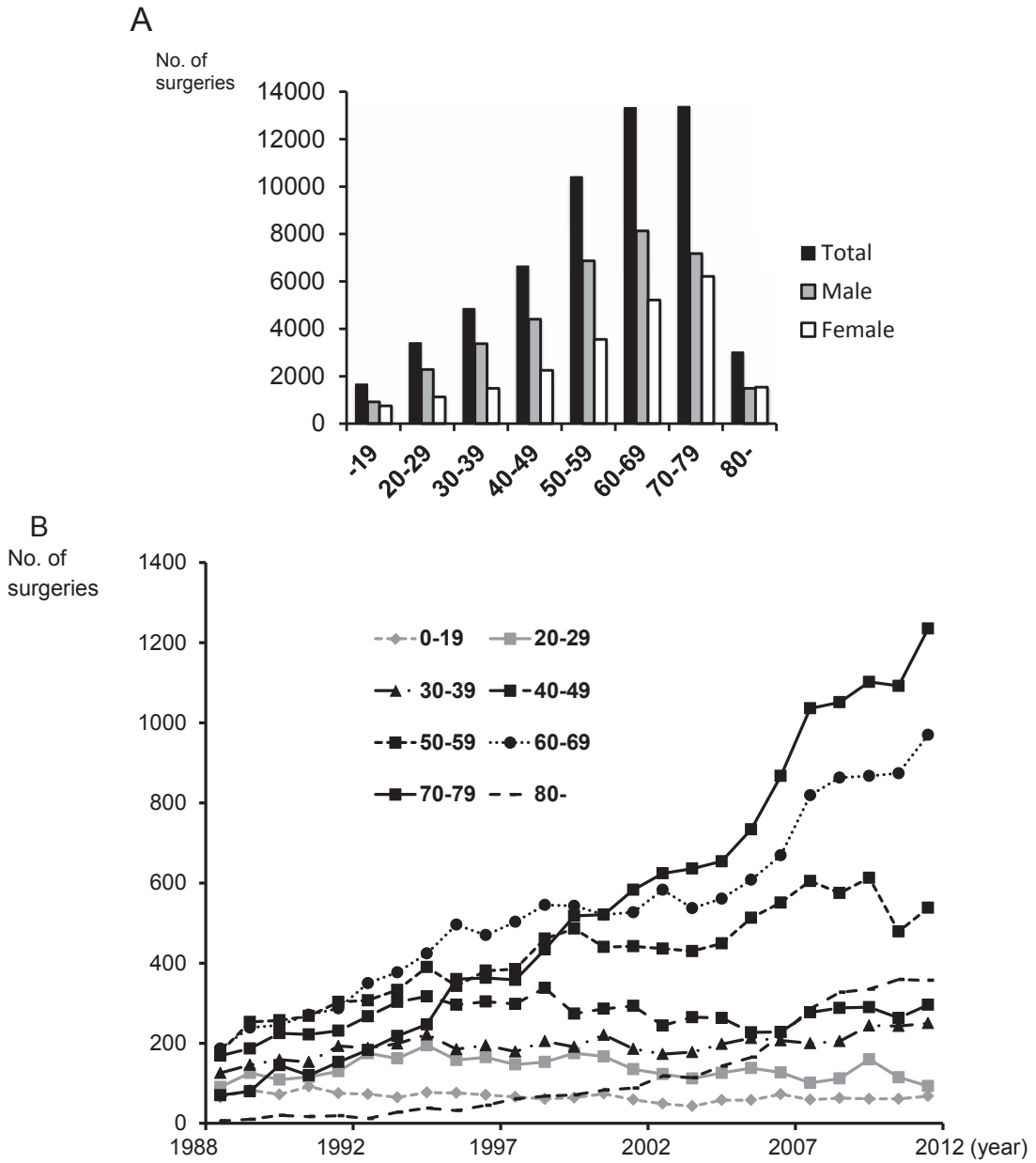

Fig. 2. Age distribution of the patients who underwent spine surgeries in Tohoku University Spine Society between 1988 and 2012.
A. The most common generation was the 8th decade among the whole and female patients, while it was the 7th decade among the male patients.
B. Annual change of the number of surgeries in each generation. The number of surgeries for patients ≥ 60 years and those of < 20 years showed remarkable contrast. The former markedly increased after around 2000, while the latter showed almost same numbers fewer than 100 during the 25 years.

1992, they have a relatively shorter history. In addition, the rate of coverage of each nation's population is not wide except for the Swespine and the NORspine (established in 2006): 9.8 million inhabitants in Sweden (as of 2014) and 5.1 million inhabitants in Norway (Strömqvist et al. 2013; Fredø et al. 2014; Fritzell et al. 2015). However, all spine departments in the countries do not necessarily join in these two spine registries: Swespine had participation of 75 % (as of 2009) and 90% (as of 2012) of all spine departments and NORspine has participation only from the government-owned hospitals and clinics (Öhrn et al. 2011; Strömqvist et al. 2013; Fredø et al. 2014). Most of the papers based on the data from those registration systems described results of surgical treatment for degenerative lumbar spinal disorders such as reoperation rates of LDH and LSS (Jansson et al. 2003, 2004, 2005; Schluessmann et al. 2009; Solberg et al. 2013; Fritzell et al. 2015). Only a few studies described cross-sectional epidemiological analysis of spinal disorders during a short period of time (Utku et al. 2010; Strömqvist et al. 2013).

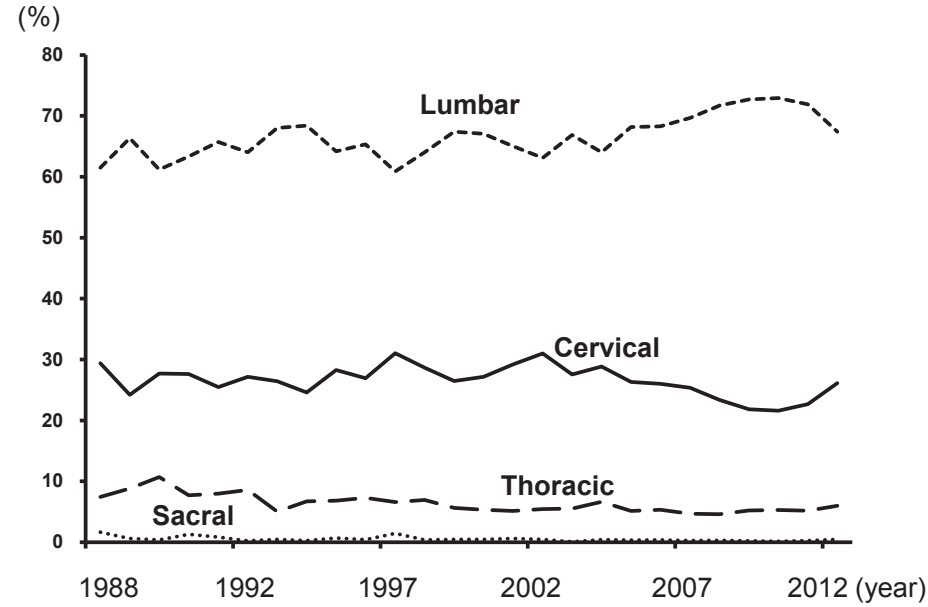

Fig. 3. Annual rates of spine surgeries at each spinal level in Tohoku University Spine Society between 1988 and 2012. The annual rate of surgeries little fluctuated at every spinal level during the 25-year study period: that at the cervical spine was between 21.6-31.0%, that at the thoracic spine was between 4.6-10.7%, and that at the lumbar spine was between 60.9-72.9%.

Table 1. Pathologies for spinal surgeries in Tohoku University Spine Society between 1988 and 2012.

	Pathology	No. of surgeries	%
Degenerative (87.4%)	Lumbar spinal stenosis*	20,364	35.9
	Lumbar intervertebral disc herniation	15,725	27.7
	Cervical myelopathy	11,214	19.8
	Cervical radiculopathy	1,207	2.1
	Thoracic myelopathy	1,081	1.9
Trauma (4.8%)	Spinal trauma	2,713	4.8
Tumor (3.9%)	Spinal cord tumor	1,258	2.2
	Metastatic spinal tumor	679	1.2
	Primary spinal tumor	268	0.5
Idiopathic/Congenital	Idiopathic scoliosis	496	0.9
(1.1%)	Congenital spinal diseases	143	0.2
Infection (0.8%)	Infectious spondylitis	469	0.8

(*including degenerative spondylolisthesis)

History of TUSS spine registry and recent changes of Japanese population

Our TUSS Spine Registry has a history of longer than 25 years since 1988. It has been collecting data of surgeries for all spinal disorders from all orthopedic departments in the Tohoku University School of Medicine and its affiliated hospitals covering around 4 million inhabitants. Using the data from the registry, the present study clarified longitudinal changes in trends of spinal surgeries in accordance with by far the most rapid aging of Japan's population over the period of a quarter century.

During the 25 year-study period, spinal surgeries increased approximately 4-fold in the annual number in our TUSS Spine Registry, which is mostly attributed to the increase of surgeries for degenerative spinal disorders. The increase, we believe, is a combined reflection of the following factors. In line with the most rapid aging of the Japanese society, the numbers of households of aged person

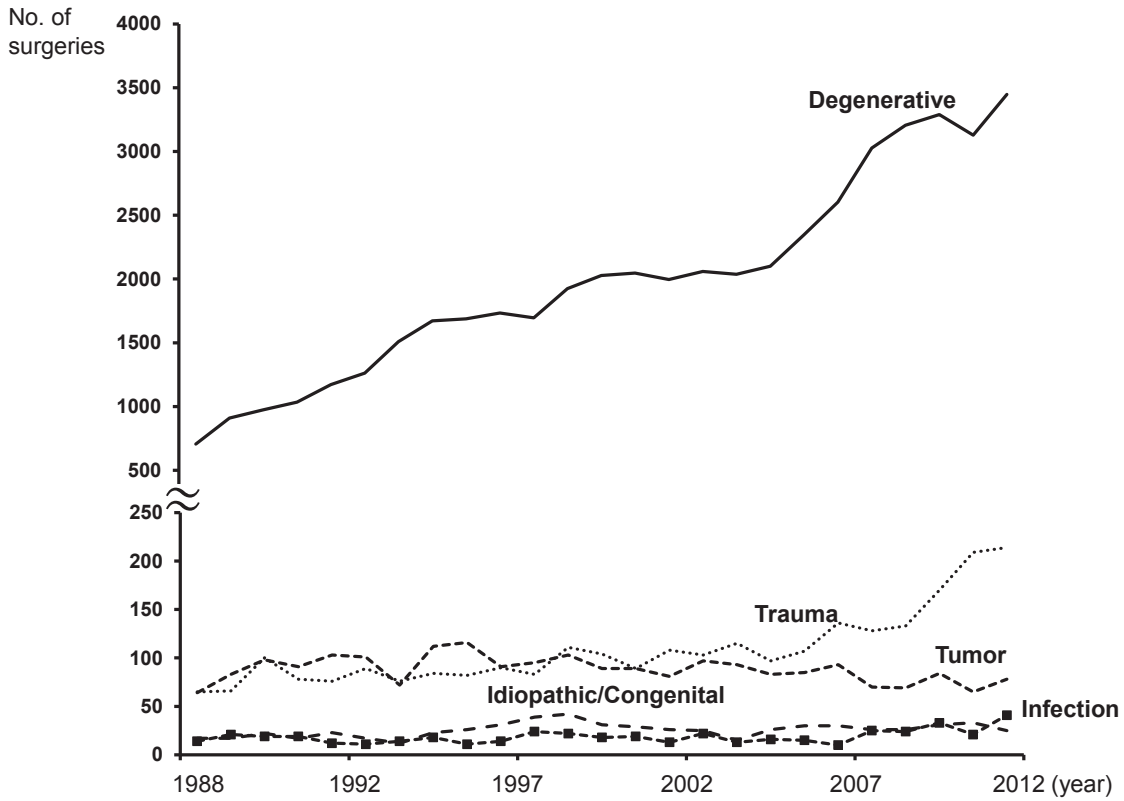

Fig. 4. Annual change of the number of surgeries in each rough pathological classification.
The annual numbers of surgeries for degenerative spinal disorders and trauma increased approximately 5-fold and 3-fold, respectively, during the study period. On the other hands, those for the other categories indicated almost steady numbers.

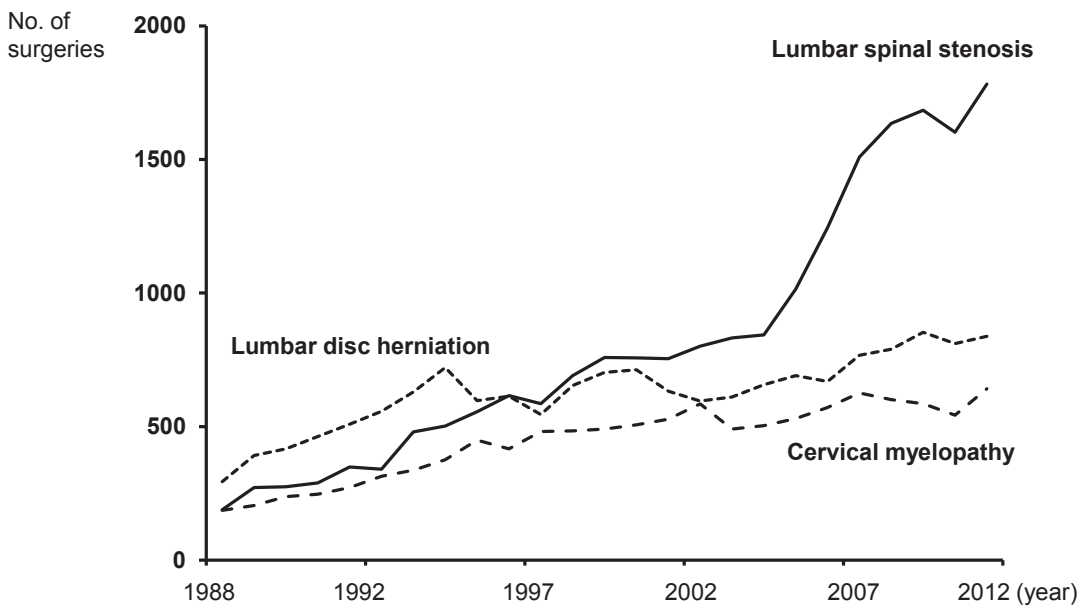

Fig. 5. Annual changes of the numbers of surgeries for the three most common spinal disorders in Tohoku University Spine Society between 1988 and 2012.
Surgeries for lumbar spinal stenosis showed remarkable growing in those 25 years. They were less than those for lumbar disc herniation before 1996 but more than twice of those for the latter in 2012.

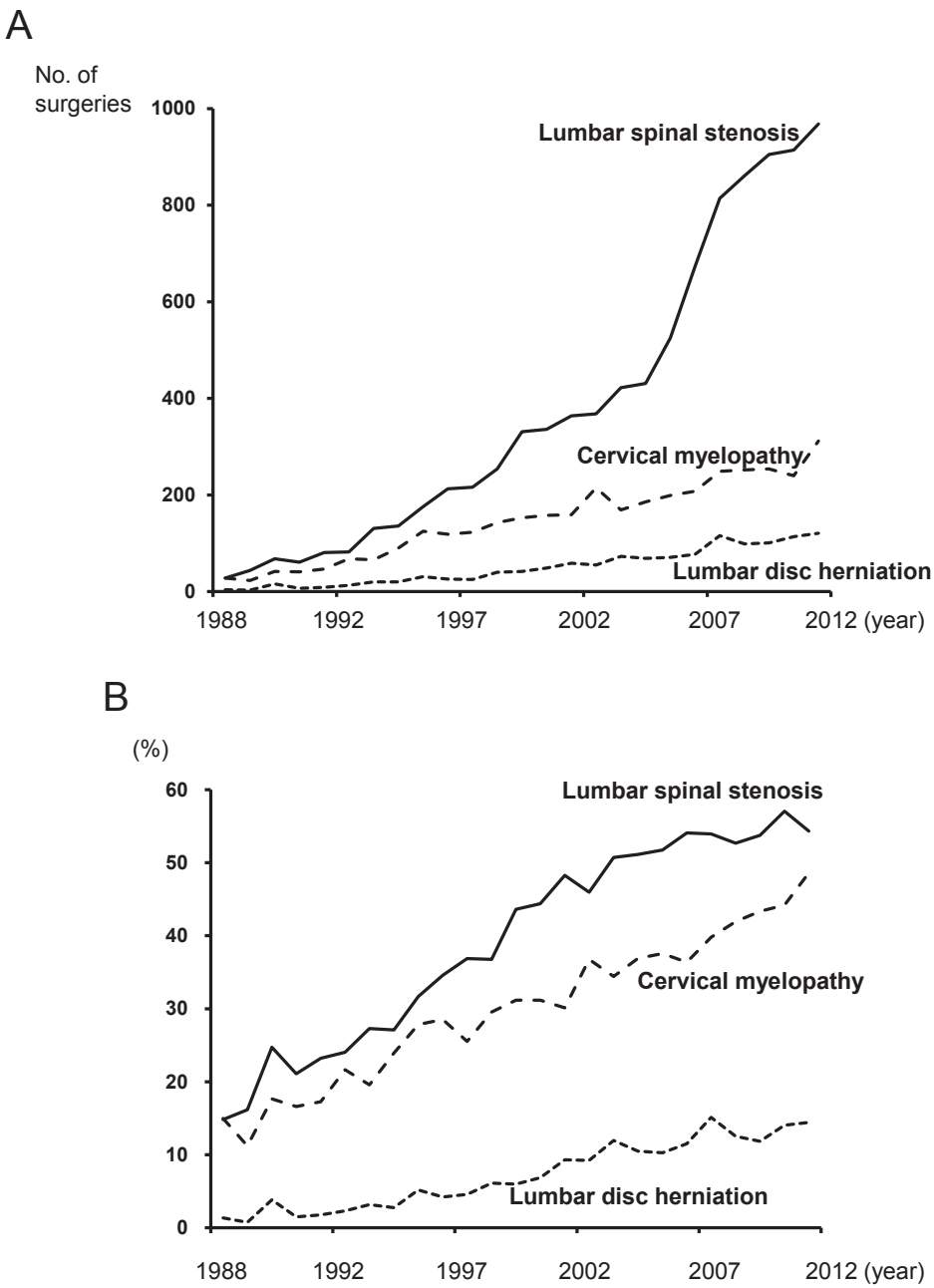

Fig. 6. Surgeries for lumbar spinal stenosis, lumbar disc herniation and cervical myelopathy patients aged ≥ 70 years.
A. Annual numbers of surgeries for patients aged ≥ 70 years with lumbar spinal stenosis, lumbar disc herniation and cervical myelopathy increased approximately 35-, 30- and 11-folds, respectively, during the period.
B. The rate of surgeries for the patients ≥ 70 years with lumbar spinal stenosis and cervical myelopathy indicated almost 3-fold increase in those 25 years. In 2012, approximately half of the patients who underwent surgery for lumbar spinal stenosis or cervical myelopathy were aged ≥ 70 year.

alone and of aged couple only considerably increased. The numbers of total households and households with at least one person aged ≥ 65 years increased approximately 1.3-fold and 1.9-fold, respectively, between 1990 and 2012. Among the latter, the numbers of households of couple only and one-person households increased 2.7-fold and 3.0-fold, respectively, and their proportion rates within the total number of households with at least one person aged ≥ 65 years grew from 25.7% to 38.5% and from 11.2% to 17.7% between 1989 and 2013, respectively (from website of Cabinet Office, Government of Japan; http://www8.cao.go.jp/kourei/whitepaper/w-2014/zenbun/s1_2_1.html, and Statistics and Information Department, Minister's Secretariat, Ministry of Health, Labour and Welfare of Japan; http://www.mhlw.go.jp/toukei/list/dl/20-21-h25.pdf). Such rapid aging and changes of family structures have caused people, particularly the elderly, to be more sensitive to active aging and healthy life years. In addition, patients have gradually

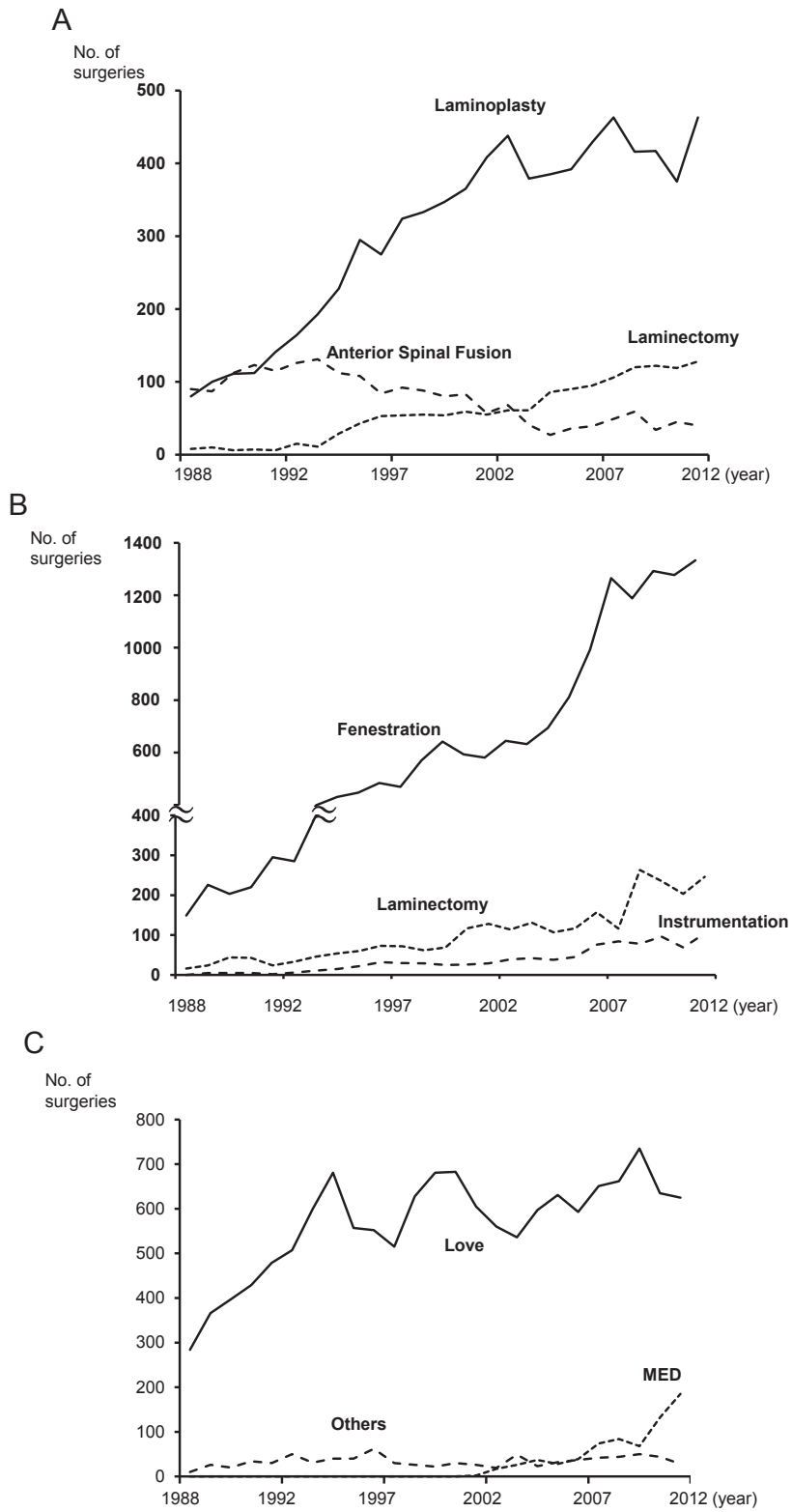

Fig. 7. Annual changes of surgical procedures for the three most common spinal disorders in Tohoku University Spine Society between 1988 and 2012.

A. Cervical myelopathy. Laminoplasty and anterior spinal fusion (ASF) covered almost all patients and shared them half and half in the first 5 years. The number of surgeries of laminoplasty indicated approximately 5-fold increase during 25 years while that of ASF showed a reduction by half.

B. Lumbar spinal stenosis. The number of fenestration surgery showed an about 10-fold increase during those 25 years and those of instrumentation surgery and laminectomy gradually increased.

C. Lumbar disc herniation. Discectomy first described by Love & Walsh (so-called Love's procedure in Japan) was the main procedure for lumbar disc herniation during the study period. After introduction of microendoscopic discectomy (MED) in 2002, the number of surgeries using MED rapidly increased.

gotten to realize the development of spinal surgery, which may have simply been thought dangerous in earlier years. As a consequence, patients, even older ones, sought consultation with little hesitation, which is sustained by the facts that in our registry, the most common generation was the 8th decade after 2002 and the 8th and patients ≥ 80 years demonstrated 18-fold and 60-fold increases, respectively, during the 25 year-study period. The number of established spinal surgeons through higher training systems also increased large enough to cover the increasing demand of spinal surgeries: the increase of spinal surgeons in our society was approximately double between 1988 and 2012.

Increase of number of surgery for degenerative spinal disorders

LSS, LDH and cervical myelopathy were the three most common spinal disorders accounting for > 80% of those for all surgeries in the present study. The numbers of surgeries for the three disorders increased during the 25 years: approximately 10-fold for LSS and 3-fold each for LDH and cervical myelopathy. Interestingly, LDH and LSS showed remarkable contrasting increases. LDH was more common than LSS in the first 9 years. However, the relation was reversed in 1997 and the differences in number became wider year-by-year. As expected from a viewpoint of pathomechanism, patients with LDH were significantly younger on average (38 years) than patients with LSS in the first year (59 years), and moreover, the ages of the latter predominantly shifted to older ages during the 25 years and reached to 69 years in 2012. The younger patients with LDH may have a surgical treatment earlier as they want to be relieved earlier and go back to their work or household tasks, which should have contributed to the increasing number of surgeries for LDH in the earlier years of the study period. However, the rapid spread of MRI machines around 1990 revealed the effectiveness of conservative treatment for LDH by spontaneous resolution of protruded disc materials (Saal et al. 1990; Saal 1996), which should have stopped or slowed the increase of surgeries for LDH after the first 7 years. On the other hand, most of older sufferers from intermittent claudication or leg numbness caused by LSS may have simply ascribed their symptoms to natural aging and reconciled themselves to their disabilities in the earlier years of the study period. In the later years, however, sufferers from such symptoms should have actively sought medical consultation, which should have been reflected in the increasing number of surgeries for LSS.

Changes of surgical trends for spinal disorders

Recommendation of surgical procedures depends on surgeons' rationales or preferences in addition to patients' physical conditions and spinal pathologies. As procedures for cervical myelopathy, ASF and laminoplasty were almost equal in number in the first year of our registry. However, ASF started gradually decreasing after several years, whereas laminoplasty greatly increased. Laminoplasty needs no handling of pathologies in front of the spinal cord such as herniated discs or ossification of the posterior longitudinal ligament and can more easily achieve multilevel decompression, which is necessary in most older patients, than ASF. It also needs no bone grafting or instrumentation for spinal fusion. Fetal complications such as esophageal rupture and respiratory involvements including laryngeal edema and postoperative pneumonia, which may affect older patients more frequently, and fusion-related complications such as nonunion and adjacent segment problems possibly occur in anterior spinal surgery (Hilibrand et al. 1999). As cervical myelopathy is common in older population, laminoplasty have been preferred to avoid such complications in addition to its neurological results have been reported to be similar to those of ASF for cervical disc herniation (Koakutsu et al. 2010; Liu et al. 2014). Accordingly, laminoplasty was more than 10-fold common than ASF in 2012.

Sole neural decompression by fenestration and discectomy through partial laminectomy were the principal procedures for LSS not only by spondylosis but also by degenerative spondylolisthesis and LDH, respectively, throughout the 25 years of our registry. Some newly developed surgical techniques and equipments caused gradual changes in choices of surgical procedures because of their dominant advantages. No instrumented spinal fusion was performed for LSS in 1988 while PLF or PLIF was chosen in approximately 6% of the cases of LSS in 2012. The main reasons of the choices were development and spread of new technology of strong and secure spinal instrumentation on and after 1990s (Malhotra et al. 2014), which has been available for LSS with instability or deformity or facetectomy necessitated for enough neural decompression. As for LDH, discectomy through open, partial hemilaminectomy was increasingly replaced by MED, in accordance with growing numbers of spine surgeons and hospitals employing such devices and techniques in our spine society since 2002. Although the replacement rate by MED and other minimum invasive spinal surgery technique was around 25% in 2012, it should be full in the near future.

Our philosophy for spinal surgery

Large differences in diagnostic criteria, surgical indications and procedures recommended by spine surgeons may make patients confused at their decision making. Our spine society, TUSS, was founded in 1987 in order to provide safe and high-quality treatment of spinal disorders in our area, which is supposed to have approximately 4 million inhabitants. Through conducting collaborative clinical studies and organizing spine operative courses for young trainees, members of the society gradually came to hold standardized ways of diagnosis and treatment and the following philosophy of 5-L in common: less invasive, less complicated, less fusion, less metal works and less expensive. The data, particularly those of degenerative spinal disorders, presented in this paper are believed to reflect the

philosophy. On the other hand, when necessary, aggressive surgeries such as long spinal fusion with instrumentation for deformity correction and spine-shortening osteotomy for tethered cord syndrome were definitely recommended to patients (Kanno et al. 2008; Kokubun et al. 2011).

Conclusion

This is the first report, to the best of our knowledge, to investigate the longitudinal changes of numbers and trends of spine surgeries in a certain area with a long period. As Japan is the most aged country in the world, the data we presented here would be a model for advanced countries in the near future which have becoming more and more aging society.

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Conflict of Interest

The authors declare no conflict of interest.

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