22

Rehabilitation for Spinal Cord Injury Caused by Thoracic Aortic Aneurysm

Ohsawa, Suguru and Hirabayashi, Shinji
Sumitomo Hospital & Osaka Rosai Hospital
Japan

1. Introduction

Aortic aneurysm (AA) is a life threatening condition. Large AA carries a substantial risk of rupture. Observational studies have reported a 14.1% annual incidence rate of aortic rupture. Once the aorta has reached a diameter of 6 cm the risk of rupture increases in proportion to the aortic diameter (Elefteriades, 2002). The 5-year cumulative risk of rupture has been estimated to be 31 % among aneurysms wider than 6 cm (Clouse et al., 1998). A ruptured thoracic aortic aneurysm (TAA) is a medical catastrophe, and the survival rate is extremely low (Johansson et al., 1995).

The incidence of thoracoabdominal aortic aneurysm (TAAA) was estimated to be 16.3 per 100,000 males and 9.1 per 100,000 females in a recent review of the Swedish National Healthcare Register, which reported increasing incidences over a 15-year period (Olsson et al., 2006). The incidence of thoracic aortic aneurysms in Rochester, Minnesota, was 5.9 per 100,000 (Bickerstaff et al., 1982).

The Swedish register study also found that the frequency of thoracoabdominal aortic surgery had increased from 7 to 15 fold during the study period. A series of 1004 patients who underwent thoracoabdominal aortic operations were reported to have a 5-year mortality of 39% compared with a matched population of untreated patients with a 5-year mortality of 87% (Miller III et al., 2004).

However, aneurysm surgery also carries a risk of death (Rectenwald et al., 2002): mortality at 30 days ranges from 4.8%-8.3% (Coselli et al., 2000; Etz et al., 2006; Greenberg et al., 2008; Svensson et al., 1993). Moreover, the complications associated with this type of surgery are devastating and unpredictable, e.g., thoracic spinal cord infarction (Crawford et al., 1970; Grace & Mattox, 1977; Sliwa & Maclean, 1992) and renal failure caused by renal artery occlusion (Coselli & Le Maire, 1999; Svensson et al., 1991; 1993), which can induce a sedentary state. Aortic aneurysm is a degenerative condition, which means that the patients with this condition are usually elderly, except for those with Marfan syndrome (Etz et al., 2006). Elderly patients are susceptible to respiratory system complications. In long operations, such as open thoracotomy, paraplegia and recurrent laryngeal nerve (RLN) palsy can also occur (discussed later), leading to respiratory system failure. Spinal cord injury (SCI) rehabilitation is hard and requires a long period of exercise. Severely impaired patients with SCI and/or respiratory failure and/or renal failure are often elderly; therefore, it is very hard for them to undergo rehabilitation. These above issues are discussed in this chapter together with our experiences.

2. Incidence of spinal cord injury after thoracoabdominal aortic aneurysm repair

The incidence of SCI as a complication of TAAA repair ranges from 8% to 28% (Greenberg et al., 2008; Messe et al., 2008). Aneurysmal expansion influences the incidence of SCI. Crawford classified aortic aneurysms into several types (Fig. 1): Type I involves most of the descending thoracic aorta and the celiac and superior mesenteric arteries but not the renal arteries. Type II involves most of the descending thoracic aorta and the abdominal aorta including all of the renal and visceral arteries. Type III involves less than half of the descending thoracic aorta and all of the abdominal aorta. Type IV involves all of the abdominal aorta including the renal and mesenteric arteries (Fig 1, Acher et al., 2008).

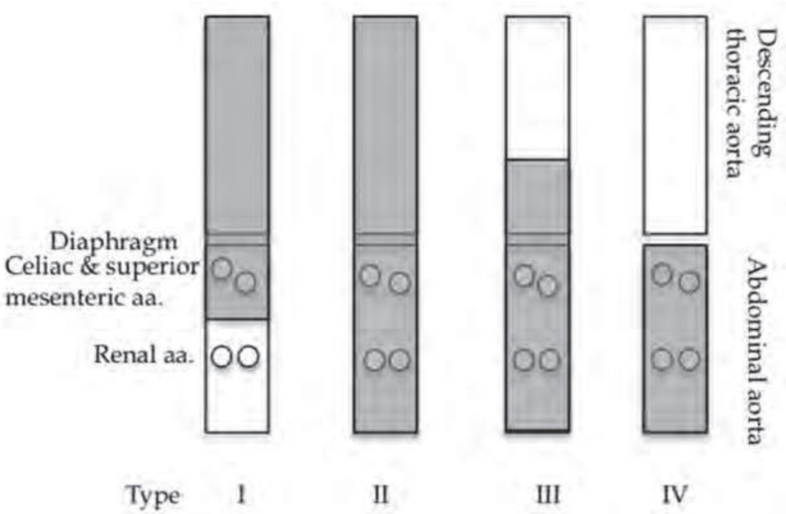

Fig. 1. Crawford classification of descending thoracic and abdominal aortic aneurysm (aneurysm: shadow)

The advent of thoracic endovascular aortic repair (TEVAR) was expected to decrease the rate of complications; however, the incidence of spinal cord infarction did not change much (3-7 %) (Table 1, Dake et al., 1998; Greenberg et al., 2008; Matsuda et al., 2010; Sinha & Cheung, 2010).

	Crawford classification	C-I	C-II	C-III	C-IV
Incidence of SCI (%)	Endovascular	10	19	5	3
Incidence of SCI (%)	Open surgery	14	22	10	2

Table 1. Incidence of spinal cord injury and TAAA Crawford classification (Greenberg et al., 2008; Sinha & Cheung, 2010)

Neurologic complications are strongly associated with mortality. Messe et al. reported that 64% of stroke patients died compared with 17% of those who did not suffer a stroke and that 39% of patients with spinal cord ischemia died compared to 14% of those without spinal cord ischemia (Table 2).

Neurologic complication	Yes	No
Mortality of AA repair (Stroke)	64%	17%
Mortality of AA repair (SCI)	39%	14%

Table 2. Mortality of aortic aneurysm repair complicated with central nervous system (Messe et al., 2008)

3. Anatomy of the spinal cord circulation

The spinal cord depends on a single longitudinal anterior spinal artery and two posterior spinal arteries for blood flow, all of which originate from the vertebral arteries. The anterior and posterior spinal arteries receive segmental circulation from segmental arteries for their blood supply; the largest of these is the artery of Adamkiewicz, which originates from the lower thoracic aorta in the majority of people (Fig 2).

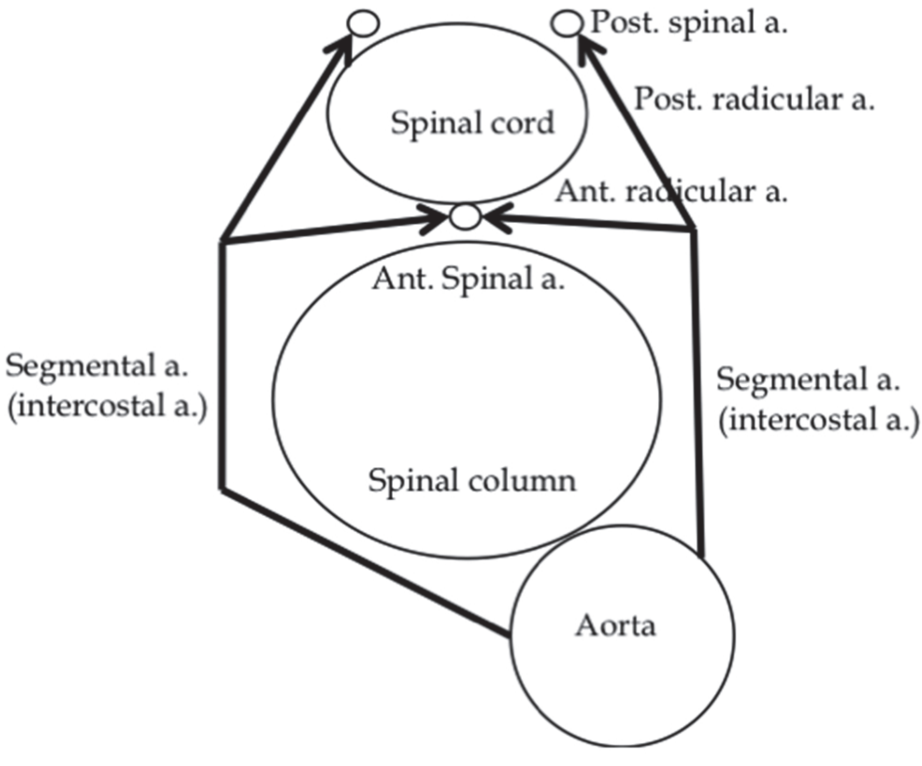

Fig. 2. The arterial supply to the spinal cord (Sliwa & Maclean, 1992)

This large intercostal (segmental) artery has various origins, but originates from T8-L1 in most patients.

Intraoperative ischemia in the spinal cord is thought to be, at least in part, related to the interruption of blood flow through these intercostal arteries due to cross-clamping of the aorta and surgical ligation during aneurysmal resection. In patients with significant thoracic aortic aneurysms, spinal cord integrity may also be maintained by an extensive network of collateral arteries, including supplies from the lumbar and pelvic circulation (Fedorow et al., 2010). Spinal cord ischemia is caused by aortic cross-clamping and interruption of the blood supply to the spinal cord via critical intercostal arteries. The cause of SCI during TAA repair is thought to depend on various factors, including clamping time, reperfusion injury, and hemodynamics. As for the arterial blood supply to the spinal cord, the mid-thoracic area is poorly vascularized with one (or occasionally no) anterior medullary artery that originates from the intercostal arteries. The distance between medullary arteries is greatest and the watershed effect is most striking in the thoracic area. Embolic processes induced by reversed flow might be responsible for reduced flow to the anterior spinal artery.

Fedorow et al. summarized the risk factors for paraplegia after open TAAA repair; emergency presentation (aortic dissection or rupture), postoperative hypotension, more extensive aneurysms (Crawford Type I or II), ligation of spinal collateral vessels, prolonged aortic cross-clamp time, previous abdominal aortic aneurysm repair, diabetes, advanced age(Fedorow et al., 2010). Similar risk factors for spinal cord ischemia after TEVAR were also listed by Sinha & Cheung; longer extent of aneurysm, hypotension, emergency operation, open operative repair, acute aortic rupture, aortic dissection, longer duration of aortic cross-clamp, failure to re-implant segmental arteries, prior distal aortic surgery, severe peripheral vascular disease, anemia (Sinha & Cheung, 2010).

In addition, periarterial edema around the very small radicular arteries as a result of ischemia- reperfusion induced inflammatory responses could play an etiologic role (Jacobs et al., 2006).

4. Prevention of paralysis during surgery

Various methods have been devised to protect against spinal cord ischemia during surgery for TAA (Bicknell et al., 2009; Tabayashi, 2005), such as cerebrospinal fluid drainage (Acher et al., 1994; Coselli, et al., 2002; Fedorow et al., 2010; Griepp et al., 1996; Griepp & Griepp, 2007), hypothermia (Griepp et al., 1996), epidural cooling (Cambria et al., 1997), monitoring of somatosensory (SSEP) (Crawford et al., 1988) and motor evoked potentials (MEP) (de Haan et al., 1997; Jacobs et al. 2006), intercostal artery reattachment (Acher et al., 2008), distal aortic perfusion (Crawford et al., 1988; Safi et al., 2003), and direct spinal cord cooling (Davison et al., 1994).

Spinal cord perfusion is regulated according to the following formula,

$$[\text{Tissue perfusion}] = [\text{Input blood pressure}] - [\text{Tissue back pressure}].$$

Maximizing systolic blood pressure increases the input pressure to the tissue, and removing spinal cord fluid reduces tissue back pressure, which reduces the need for significant input pressure (Acher & Wynn, 2009). This technique can be performed safely with excellent technical results (Estrera et al., 2009).

Reducing the risk further may be dependent on identifying radicular perforators that are critical to the spinal cord blood supply between the cephalad and caudal supply. Spinal cord angiography was used to identify the main supply to the spinal cord (Kieffer et al., 2002). In another study, MRI was used for the detection of the Adamkiewicz artery (Kawaharada et al., 2004), and multidirectional row CT has also been used for the same purpose (Shiiya et al., 2009). The Adamkiewicz artery is the major blood supply to the lumbar spinal cord, and its reimplantation after TAA surgery reduced the risk of paralysis to 5-6%. However, other radicular perforators may also be critical in some patients (Acher et al., 2008). A group from Mount Sinai Hospital discussed avoiding back-bleeding through the intercostal and lumber arteries, in order to prevent loss from the collateral circulation to the spinal cord, by sacrificing the segmental arteries before opening the aneurysm. As a result, the postoperative paraplegia rate in their series was 2% (Etz et al., 2006). However, when more than 10 arteries were sacrificed, the risk of paraplegia increased 29 fold (Gripp et al., 1996).

Monitoring nerve potentials (especially MEP) has been used to identify important vessels, and their reimplantation reduced the risk of paralysis even further (to below 5%) (Sloan, 2008). However, in a prospective study, SSEP monitoring and temporary distal aortic perfusion did not reduce the prevalence of early or delayed neurologic complications after surgery for thoracic aortic aneurysm (Crawford et al., 1988). One reason for the failure of SSEP to identify patients at risk is that the response of the dorsal columns to spinal cord ischemia is slow and does not reflect motor function (de Haan et al., 1997). However, MEP monitoring is an effective technique for detecting spinal cord ischemia within minutes, as a guide for the distal aortic perfusion technique, and for identifying segmental arteries that need to be preserved (de Haan et al., 1997).

Safi et al. reported that distal aortic perfusion and cerebrospinal fluid drainage (DAP+CFD) were safe and effective; immediate neurologic deficits occurred in 36 (3.6%) of 1004 patients overall, including 18 (2.4%) of 741 who received DAP+CFD and 18 (6.8%) of 263 who did not ($p<0.0009$). Among patients with high-risk Crawford type II aneurysms, 11 (6.6%) of 167 who received the DAP+CFD and 11 of those who did not (29%) suffered immediate neurologic deficits (Table 3, Safi et al., 2003).

DAP+CFD	Overall	Yes	No
Rate of neurologic deficit	36/1004 (3.6%)	18/741 (2.4%)	18/263 (6.8%)

Table 3. The effects of distal aortic perfusion (DAP) and cerebrospinal fluid drainage (CFD) (Safi et al., 2003)

After the release of the cross-clamp, the spinal cord is at further risk of ischemia secondary to hypercapnia and hypotension, which can result in decreased tissue perfusion. Metabolic acidosis after the release of the cross-clamp causes an increase in cerebral blood flow, resulting in increases in intracranial pressure and cerebrospinal fluid pressure (Fedorow et al., 2010), which increase tissue back pressure, leading to decreased spinal cord perfusion due to ischemia.

Epidural morphine for postoperative pain relief also carries a risk of paraplegia. Kakinohana et al. reported morphine-induced motor dysfunction after spinal ischemia and relief of the paralysis via the injection of naloxone and investigated the mechanisms responsible for these effects using an animal model (Kakinohana et al., 2003; Nakamura et al., 2004). Acher et al. reported good clinical results for naloxone treatment and cerebral spinal fluid drainage (Acher et al., 1994). The strategies to prevent and treat spinal cord ischemia are summalized in Table 4.

- Minimize spinal cord ischemia time:
    1. Segmental reconstruction of the descending aorta
    2. Distal aortic perfusion with a passive shunt
    3. Partial left heart bypass
- Increase tolerance of ischemia:
    1. Deliberate mild systemic hypothermia
    2. Deep hypothermic circulatory arrest
    3. Selective spinal cord hypothermia by epidural cooling
    4. Pharmacologic neuroprotection
- Augmentation of spinal cord perfusion:
    1. Deliberate hypertension
    2. Lumber cerebrospinal fluid (CSF) drainage
    3. Preservation of subclavian artery flow
- Early detection of spinal cord ischemia:
    1. Intraoperative MEP
    2. Intraoperative SSEP monitoring
    3. Serial postoperative neurologic examination

Table 4. Strategies to prevent and treat spinal cord ischemia (Sinha & Cheung, 2010)

5. Elderly patients: Dysphagia and aspiration pneumonia

In the general population, studies have shown a number of changes that result in the gradual loss of respiratory system function with advancing age (Robbins et al., 1992). Langmore et al. reported that predictors of aspiration pneumonia in elderly people were being dependent for feeding, dependent for oral care, the number of decayed teeth, tube feeding, more than one medical diagnosis, the number of medications being taken, and smoking (Table 5, Langmore et al., 1998).

- Dependent for feeding
- Dependent for oral care
- Decayed teeth
- Tube feeding
- Complications
- Medications
- Smoking

Table 5. Predictors of aspiration pneumonia (Langmore et al.)

Older age at the time of injury is also associated with a higher risk of respiratory complications. The combined effects of SCI and older age are likely to pose a significant risk of respiratory tract complications, such as pneumonia and atelectasis (Charlifue et al., 2010). The most commonly considered mechanism is pulmonary aspiration of the gastric contents, resulting in acid-induced injury. Beta agonists might contribute to gastroesophageal reflux (GER) by decreasing lower esophageal pressure (Yamaya et al., 2001). GER probably occurs more often when the patient is bedridden, and vomiting may be more frequent in patients with GER, adding to the risk of aspiration pneumonia (Feinberg et al., 1990). Aspiration pneumonia contributes to infection of the lung due to the aspiration of bacteria contained in oropharyngeal or gastric secretions. Normal hosts are less likely to develop pneumonia (Barish et al., 1985) because they either aspirate smaller volumes or are able to clear bacteria rapidly. But, an extremely small volume (0.01 ml) of saliva can contain pathogenic numbers of bacteria, and elderly patients with a predisposition to aspiration frequently aspirate oropharyngeal or gastric secretions containing high numbers of bacteria (Bartlett et al., 1974; Johanson & Harris, 1980; Toews et al., 1990). The progressive loss of protective swallowing and cough reflexes with age is thought to be one of the major risk factors for aspiration pneumonia in older people (Pontoppidan & Beecher, 1960). Impaired swallowing and cough reflexes have been demonstrated in elderly patients who develop aspiration pneumonia (Nakazawa et al., 1993; Sekisawa et al., 1990; Yamaya et al., 2001), as has a high incidence of silent aspiration in elderly patients with community-acquired pneumonia (Kikuchi et al., 1994); nevertheless, normal elderly people display no deterioration in their coughing reflex (Katsumata et al., 1995) (Table 6).

- Loss of respiratory system function
- GER
- Impaired swallowing
- Silent aspiration
- Impaired cough reflex

Table 6. Characteristics of elderly patients

Leder & Ross reported that 29% of the total referral population in an tertiary-care teaching hospital exhibited aspiration while 44% of patients with vocal fold immobility aspirated, indicating that vocal fold immobility was associated with a 15% increased incidence of aspiration in patients already suspected of dysphagia. Left vocal fold immobility most frequently occurred due to surgical trauma (60%). A liquid bolus was aspirated more often than a puree bolus (Leder & Ross, 2005). Aspiration caused by RLN palsy has also been reported (Heitmiller et al., 2000; Perie et al., 1998). As a consequence, the nerve is particularly vulnerable to pathological conditions involving these structures (Ortner, 1897; Thirlwall, 1997; Woodson & Kendrick, 1989). In cases of thoracic aortic aneurysm, the incidence of left RLN (LRLN) palsy has been reported to range from 5% to 12% (Stoob et al., 2004). The incidence of LRLN palsy was 8.6% in a study of 500 patients (de Bakey et al., 1978) and 5% in another study of 168 cases (Teixido & Leonetti, 1990). Ishimoto et al. reported an incidence of vocal cord immobility of 32% (20/62), which was confirmed by laryngoscopy after surgery for TAA, and 16 out of 19 patients (84 %) who were followed for more than 6 months did not fully recover (Ishimoto et al., 2002)
As shown in Table 7, postoperative paraplegia closely related to respiratory failure. Crawford Type II aneurysms occurred in 32% of patients with respiratory failure and in 28% of the patients that developed postoperative pneumonia (Money et al., 1994). Five out of seven patients with total paraplegia developed respiratory failure (86%) and that 7 of the 14 patients (50%) with muscle weakness developed respiratory failure, whereas respiratory failure developed in 29 (38%) patients with normal muscle function (p=0.041) (Svensson et al., 1991).

Muscle function	Paraplegia	Paraparesis	Normal
Respiratory failure	5/7 (86%)	7/14 (50%)	29/77 (38%)

Table 7. Paraplegia and respiratory failure (Svensson et al., 1991)

6. Rehabilitation of spinal cord injury in elderly patients

For patients who suffer spinal cord injuries during surgery for AA, the mortality rate is high: Kiwerski et al. reported that 18 out of 74 (24%) patients with traumatic paraplegia died during rehabilitation (Kiwerski et al., 1992). Life-threatening complications are more frequent following spinal cord injuries in elderly patients. This dangerous situation is caused by several factors including a diminished inspiratory reserve volume, circulatory system disease, and poor tolerance to prolonged immobilization (Kiwerski et al., 1992).

Searching the SCI databases in Japan (Sumida et al., 2001a; 2001b) and the USA (Chen et al., 1999; DeVivo et al., 1999; Eastwood et al., 1999; Graves et al., 1999; Hall et al., 1999; Marino et al., 1999) revealed that the complication rates of pneumonia and aspiration were higher in our cases (Ohsawa et al., 2008).

Fig. 3. Basic exercises for patients with SCI (long sitting, roll over, transfer to wheel chair)

Elderly patients with thoracic SCI receive rehabilitation as following exercises; a shot-legged sitting on the edge of the bed, transfer to wheelchair in a ward, then, roll over, long leg sitting, wheelchair drive in rehabilitation center. However, upper limb muscle weakness, excess body weight, renal failure which causes restricted exercise times, respiratory failure, decubitus, all these factors drive them deconditioned and sedentary state. Motor scores of functional independence measure of our patients (FIM, Table 8; Granger et al., 1986; Ottenbacher et al., 1996) before rehabilitation and at discharge were also lower than those in the databases, as were the gain in FIM and the rate of FIM gain during hospitalization.

Finally, SCI associated with thoracic aortic aneurysm surgery was especially marked in the elderly patients requiring airway assistance such as intubation, tracheostomy, or mini-tracheostomy. Due to the long operation time, tracheal secretion is increased, resulting in longer stays in intensive care units and a worse state (Fig 4).

The abovementioned problems can easily worsen a patient's general condition, and such the resultant vicious cycle leads to a poor prognosis. DeVivo et al. reported a high mortality rate for traumatic spinal cord injury older patients (61-86 years-old), who tend to be complicated with pneumonia, (p=0.031); moreover, for survivors in the oldest age group (61-86), there was a high likelihood of having to live in a nursing home (DeVivo et al., 1990).

The incidence of pressure sores was very high in our series. In the Japanese database, the incidence is 45.4% for the complete paraplegic SCI patients aged 30 years or higher and 17.3% for those aged less than 30 years. However, the United State database showed no difference in age (23.7%). These results can be attributed to the smaller nursing facilities in Japan (Table 9).

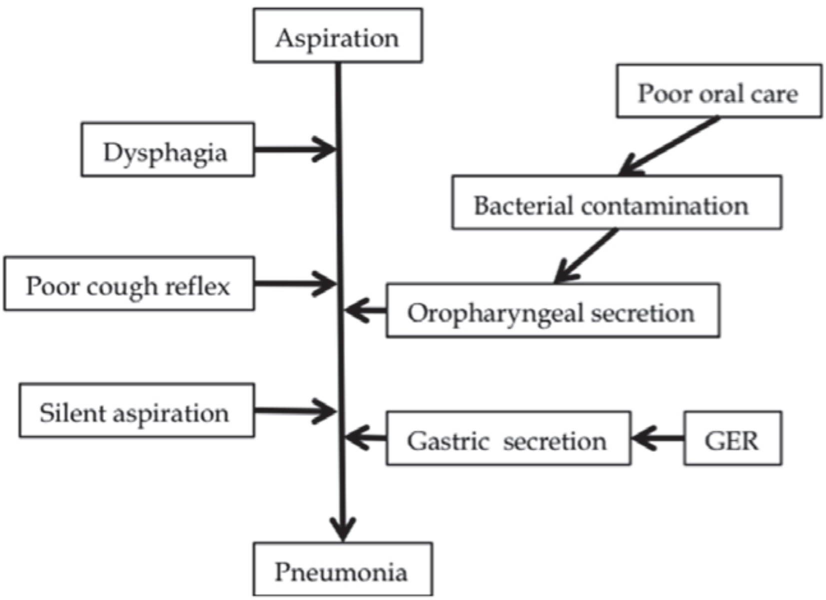

Fig. 4. Aspiration pneumonia in elderly patients

FIM (motor)

- Self care
  1. Eating
  2. Grooming
  3. Bathing
  4. Dressing upper body
  5. Dressing lower body
  6. Toileting
- Sphincter control
  1. Bladder management
  2. Bowel management
- Transfer
  1. Bed, chair, wheelchair
  2. Toilet
  3. Tub
  4. Shower
- Locomotion
  1. Walk/wheelchair
  2. Stairs

FIM (cognitive)

- Communication
  1. Comprehensive
  2. Expression
- Social cognition
  1. Social interaction
  2. Problem solving
  3. Memory

Table 8. FIM domain (Ottenbacher et al., 1996)

	Our cases	Japanese database> 30 years old	Japanese database < 30 years old	USA database
Incidence	11/19 (58%)	45.4%	17.5%	23.4%

Table 9. Incidence of pressure sore

Special consideration to swallowing and deglutitive rehabilitation is needed (Table 10, Honda & Mizojiri, 2000).

- Auscultation: swallowing sound, respiratory sound (Fig 5)
- Water drinking test (1ml, 30ml)
- RSST (repetitive saliva swallowing test)
- Videofluoroscopic swallowing study (VFSS)
- Fiberoptic endoscopic examination of swallowing (FEES)

Table 10. Assessment of swallowing

Fig. 5. Auscultation

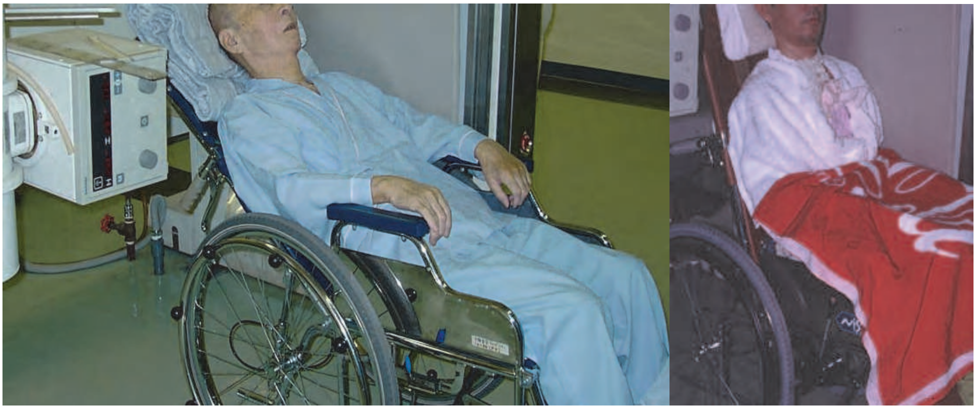

Fig. 6. Positions of VFSS, keeping neck flexion to avoid aspiration during eating

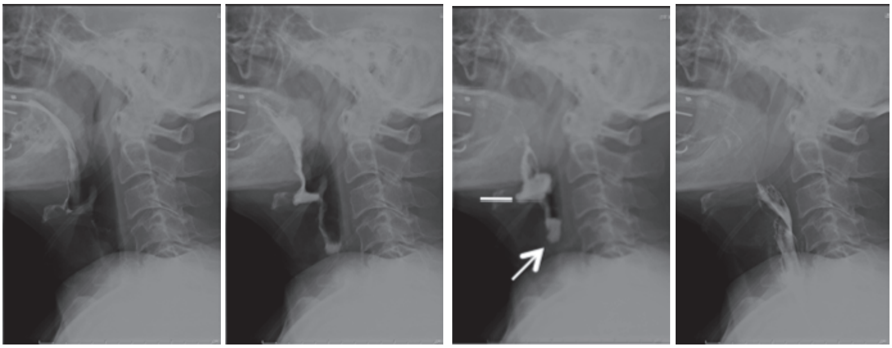

Fig. 7. VFSS (74 year-old man), series of a swallow, no aspiration, delayed swallowing, pooling bolus in the vallecular pouch (line) and the piriformis sinus (arrow) with thick iopamidol liquid

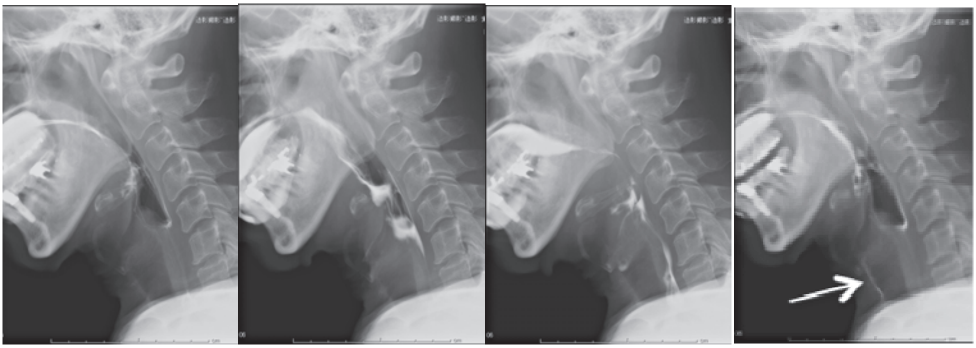

Fig. 8. VFSS (57 year-old man), series of a swallow, thin iopamidol liquid, aspiration (arrow)

This could involve the use of diagnostic tools such as videofluoroscopic study (Fig 6,7,8,) and endoscopy (Langmore, 2003); oral care to prevent pneumonia (Fig 9, Yoneyama et al., 1999);

Fig. 9. Oral care by dental hygienists

neck muscle exercises to improve swallowing activity (Shaker et al., 1997); and the monitoring of food temperature, which affects the swallowing reflex; i.e., temperatures above and below body temperature accelerate the triggering of the swallowing reflex (Watando et al., 2004).
The final outcome in our series was poor. Only one third of the patients were able to live independently in their homes. One of the reasons for this was that their main caregiver was often also old. This dearth of care potential led to long-term care in hospitals (Ohsawa et al., 2008).

7. Factors influencing outcomes

In our series, two elderly women (78 and 80 years old) died during hospitalization. Both of them had TAA complicated with aspiration pneumonia. One of them experienced intubation, and the other underwent mini-tracheostomy. One of them had LRLN palsy, which was diagnosed postoperatively with a laryngoscope. Both of them had a long smoking history. They also had renal failure, and one of them was receiving haemodialysis, which meant that they became sedentary and it was difficult for them to undergo rehabilitation therapy every day. Their poor general condition led to a delay in the start of rehabilitation. Only pulmonary rehabilitation and range of motion exercises were performed in the intensive care unit. They also suffered sacral decubitus due to deterioration of their general condition and long bed rest. In general, among elderly patients with vascular ischemic spinal cord injury, males were more independently mobile than females (Kay et al., 2010).

In our series, our previously reported cases and seven recently rehabilitated patients; i.e., a total of 19 patients, were analyzed. Two died in hospital, and another patient died 13 months after the operation. The American Spinal Injury Association (ASIA) (Table 11, Ditunno et al., 1994, Maynard et al., 1997) motor score at the beginning of the rehabilitation was 55.8 points, and the mean improvement was 7.9 points, giving a mean score of 64.0 points at discharge. The motor FIM at the beginning of rehabilitation was 31.4, and the mean improvement was 26.1 points, giving a mean score of 59.4 points at discharge (Table 12).

Key muscles

- C5: elbow flexors
- C6: wrist extensors
- C7 elbow extensors
- C8: Finger flexors to the middle finger
- T1: small finger abductors
- L2: Hip flexors
- L3: knee extensors
- L4: Ankle dorsiflexors
- L5: Long toe extensors
- S1: Ankle plantar flexors

Table 11. ASIA motor score (Marino et al., 1999; Maynard et al., 1997), numerical sum of motor grades of all key muscles as determined by motor testing

Six patients were referred to another hospital. The other three were transferred to a long-term care hospital such as a nursing home. Renal failure and LRLN palsy occurred in four and nine cases, respectively, before rehabilitation. In eight of the nine cases, LRLN palsy probably developed perioperatively. Postoperatively, seven patients suffered respiratory failure that was managed with intubation, tracheostomy, or mini-tracheostomy. Sacral decubitus developed in nine patients and in other regions in three. Most of them had slightly reddish skin on the sacral region without ulcer formation. As shown in Table 12, we compared the gain in motor FIM during hospitalization and the rate of this gain with those in the reported databases. The independent patients at home had a mean gain in motor FIM of 37 points, and their rate of improvement was also very high ((gain of mFIM/LOS); 0.30 (0.17)) compared with those of the other patients, who had comparatively good outcomes for non-traumatic SCI patients (Kay et al., 2010; New & Epi, 2005; Yokoyama et al., 2006). Our series were obtained from an acute care hospital, and selected patients were transferred to tertiary rehabilitation centers. Most traumatic SCI patients will be in a similar situation. Hagen & Kennedy reported that elderly patients with traumatic SCI also displayed significant improvement during rehabilitation (Hagen et al., 2005; Kennedy et al., 2003).

	Our case, mean (SD)	Japanese database	USA database
Pneumonia	5/19	3.7%	15.2%
Aspiration	5/19	n	1.5%
mASIA at start	55.8 (17.1)	48.5 (28.6)*	50-74**
mASIA at discharge	64.0 (19.3)	61.4 (29.5)*	51-81**
Gain of mASIA	7.9 (9.3)	12.9 (14.5)*	2.6-21.0**
mFIM at start	31.4 (16.7)	37.6	33.3
mFIM at discharge	59.4 (26.7)	71	72.7
Gain of mFIM	26.1 (14.5)	34.1	39.4
Gain/LOS	0.19 (0.14)	0.21	0.72

* paraplegia+tetraplegia, ** reported according to each Frankel grade (A-D)

Table 12. Comparison between the databases of thoraco-lumbar SCI (Ohsawa et al, 2008 with further cases added) mASIA: ASIA motor score, mFIM: motor FIM, LOS: length of stay, n: not mentioned,

8. Conclusions

In conclusion, thoracic aortic aneurysm surgery has improved in recent years, and better outcomes are now being achieved. However, when thoracic aortic aneurysm surgery is complicated with SCI, respiratory complications, or renal failure, it is life threatening. Such complications produce a vicious cycle, which worsens outcomes. This vicious cycle can be broken by intensive and comprehensive rehabilitation. Smoking ban before operation and pulmonary rehabilitation in perioperative period improve patients' cardiopulmonary conditions. Checking hoarseness and aspiration by auscultation before food intake under safe position (maintaining 30-degree head of the bed elevation with neck flexion) are mandatory. After suture removal, muscle exercise of the upper limb and reducing body weight are encouraged. Then, comprehensive spinal cord injury rehabilitation started. Above precautious rehabilitation plan drives them better condition than that of reported (Fig 10).

9. Abbreviations

AA: aortic aneurysm, ASIA: American spinal injury association, CFD: cerebrospinal fluid drainage, DAP: distal aortic perfusion, FEES: fiberoptic endoscopic examination of swallowing, FIM: functional independence measure, GER: gastroesophageal reflux, LOS: length of stay, LRLN: left recurrent laryngeal nerve, MEP: motor evoked potential, mFIM: motor FIM , RLN: recurrent laryngeal nerve, SC: spinal cord, SCI: spinal cord injury, SSEP: somatosensory evoked potential, TAA: thoracic aortic aneurysm,
TAAA: thoracoabdominal aortic aneurysm, TEVAR: thoracic endovascular aortic repair,
VFSS: videofluoroscopic swallowing study

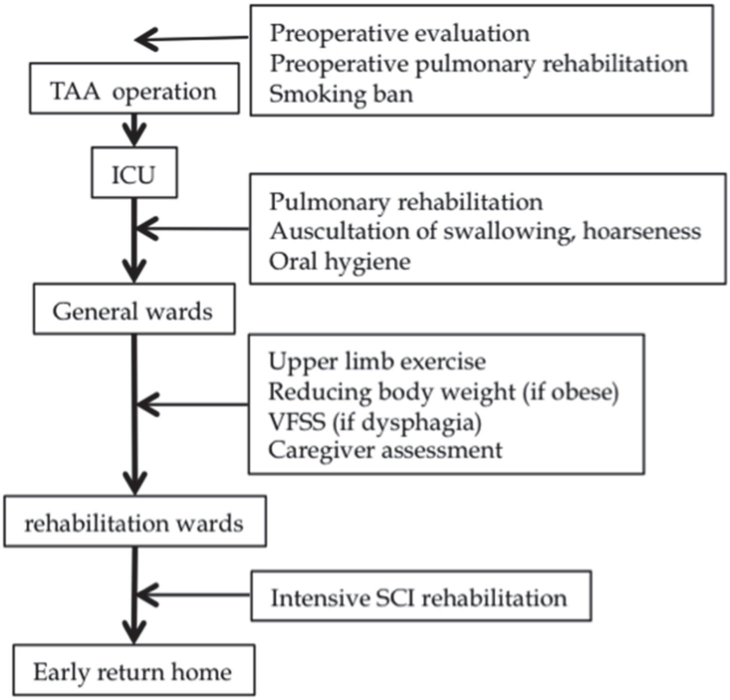

Fig. 10. Comprehensive rehabilitation for thoracic aortic aneurysm repair

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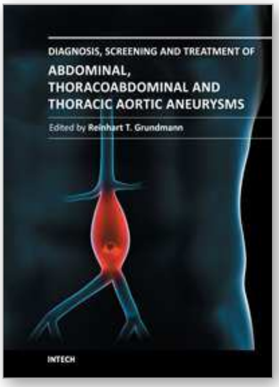

Diagnosis, Screening and Treatment of Abdominal, Thoracoabdominal and Thoracic Aortic Aneurysms

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This book considers mainly diagnosis, screening, surveillance and treatment of abdominal, thoracoabdominal and thoracic aortic aneurysms. It addresses vascular and cardiothoracic surgeons and interventional radiologists, but also anyone engaged in vascular medicine. The high mortality of ruptured aneurysms certainly favors the recommendation of prophylactic repair of asymptomatic aortic aneurysms (AA) and therewith a generous screening. However, the comorbidities of these patients and their age have to be kept in mind if the efficacy and cost effectiveness of screening and prophylactic surgery should not be overestimated. The treatment recommendations which will be outlined here, have to regard on the one hand the natural course of the disease, the risk of rupture, and the life expectancy of the patient, and on the other hand the morbidity and mortality of the prophylactic surgical intervention. The book describes perioperative mortality after endovascular and open repair of AA, long-term outcome after repair, and the cost-effectiveness of treatment.