Original
Article

Cost-Benefit Performance Simulation of Robot-Assisted Thoracic Surgery As Required for Financial Viability under the 2016 Revised Reimbursement Paradigm of the Japanese National Health Insurance System

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Purpose: To discuss the cost–benefit performance (CBP) and establish a medical fee system for robotic-assisted thoracic surgery (RATS) under the Japanese National Health Insurance System (JNHIS), which is a system not yet firmly established.

Methods: All management steps for RATS are identical, such as preoperative and postoperative management. This study examines the CBP based on medical fees of RATS under the JNHIS introduced in 2016.

Results: Robotic-assisted laparoscopic prostatectomy (RALP) and robotic-assisted partial nephrectomy (RAPN) now receive insurance reimbursement under the category of use of support devices for endoscopic surgery (\$5420 and \$3485, respectively). If the same standard amount were to be applied to RATS, institutions would need to perform at least 150 or 300 procedures thoracic operation per year to show a positive CBP (\$317 per procedure as same of RALP and \$130 per procedure as same of RAPN, respectively).

Conclusion: Robotic surgery in some areas receives insurance reimbursement for its “supportive” use for endoscopic surgery as for RALP and RAPN. However, at present, it is necessary to perform da Vinci Surgical System Si (dVSi) surgery at least 150–300 times in a year in a given institution to prevent a deficit in income.

Keywords: robot-assisted thoracic surgery, da Vinci Surgical System, cost–benefit performance, Japanese National Health Insurance System

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Introduction

The explosion in advanced medical technology has yielded the nation huge benefit. However, this has only been achieved at great cost, and in particular the increase in medical costs is one of the thorniest national policy problems that remain to be settled. When we contemplate the cooperation and globalization of economic distribution among countries surrounding the Pacific, policy like the strategic economic Trans-Pacific Partnership

(TPP) and similar agreements of the future, Japan, which possesses a renowned medical national health insurance system must consider system management more carefully regarding its future. Making economic projections concerning the medical cost situation is a precarious science. It was against such a background, that extensive revisions of the Japanese National Health Insurance System (JNHIS) reimbursement, including those for general thoracic surgery, were implemented in April 2014 and April 2016, and medical insurance reimbursement of video-assisted thoracic surgery (VATS) for mediastinal and pulmonary malignant disease was also established.

In Japan, robotic-assisted laparoscopic prostatectomy (RALP) has been a recognized application for reimbursement by the JNHIS of the Ministry of Health, Labour and Welfare, but only since April 2012. RALP receives insurance reimbursement under the category of the use of support devices for endoscopic surgery, to the extent of \$5420. Subsequently, robot-assisted partial nephrectomy (RAPN) for small renal cell carcinomas (cT1N0M0) has also become eligible for reimbursement by the JNHIS since April 2016. According to several investigations of cost-effectiveness in countries outside Japan, robot-assisted thoracic surgery (RATS) has a financial deficit from the point of view of health economics in comparison with VATS,¹⁻⁶⁾ despite differences in the medical health insurance systems. Other clinical fields are still waiting for reimbursement for the da Vinci Surgical System (dVS) operations, for example, gastrectomy, hysterectomy, and thymectomy. Nevertheless, dVS operations are now increasing rapidly in Japan. The total number of dVS operations in Japan was only approximately 200 in 2009, but grew to 9737 in 2014 and 13228 in 2015.⁷⁾ Rapid governmental decisions concerning JNHIS applications for dVS operations are necessary to enable many other procedures. In the general thoracic surgery field, the scientific foundation of robotic surgery in terms of improved outcome for myasthenia gravis after robotic thoracoscopic thymectomy has been shown by various reports compared with thoracoscopic thymectomy and they have revealed that robotic lobectomy for early-stage non-small-cell lung cancer has acceptably low morbidity and mortality and long-term stage-specific survival.⁸⁻¹²⁾ Consequently, robotic surgery has gradually produced improved clinical outcomes, rendering it attractive for many surgeons. In comparing RATS to VATS, it is necessary to review different kinds of correspondence, especially in terms of cost-benefit performance (CBP), for situations in which

robotic surgery may be covered by the JNHIS, probably in the near future.

Methods

All patients who underwent RATS in our hospital provided written informed consent after full explanation of the investigational nature of the procedures, and the study was approved by the institutional review board. We performed RATS to establish the technique of robot-assisted surgery (RAS) procedures and determine its medicoeconomic aspects in thoracic diseases.¹³⁻¹⁷⁾ All costs were borne by the hospital in all cases, as was the situation in our previous report.⁶⁾

We employed the dVS (Intuitive Surgical, Inc., Sunnyvale, CA, USA) for RATS. Intuitive Surgical Inc. reduced the equipment fee from October 2014 and also reduced the maintenance costs from July 2012. This study was carried out based on the costs of the newer da Vinci Surgical System Si (dVSi) which had become more affordable, as described above and in **Table 1**.

The JNHIS covers the entire nation of Japan, and as medical copayment the patients have to pay only 30%, with all residual medical expenses being paid by the government.⁶⁾ The cost of RATS in Japan is of course greatly affected by the cost of the operator-controlled module, the ancillary equipment, and maintenance costs, but not by the surgeon's fee. Surgeons are paid a fixed salary determined by each university hospital, which affects the medical costs determined by the Ministry of Health and Welfare in Japan, regardless of the number or types of surgical procedures they perform.

All data included in the figures and tables are calculated at ¥100 = \$1, which was the exchange rate as of September 2016.

Role of the funding source

All medical expenses for actual medical examinations and treatment for patients were paid for by Tokyo Medical University Hospital.

Results

The additional costs varied according to the type of procedure. In general, the use of RATS costs over \$6000 per procedure in Japan, since October 2014, after the pricing decision on the cost of dVSi and other instruments by Intuitive Surgical Inc. The following reference data indicate the details of the reduction in cost for the

Table 1A JNHIS costs/RTAS cases after 2016 price revisions for dVSi Single Console procedures

\$1 = 100 yen on September 2016

Contents	Items	Cost: US \$
Surgeon's fee		\$0
dVSi equipment fee		\$4464*
Medical materials	Cadiere forceps (usable in 10 procedures)	\$284
	Monopolar curved scissors (usable in 10 procedures)	\$454
	Maryland bipolar forceps (usable in 10 procedures)	\$383
	Permanent cautery spatula (usable in 10 procedures)	\$284
	Drape, instrument arm (disposable)	\$64
	Drape, camera arm (disposable)	\$60
	Drape, camera (disposable)	\$58
	Cannula seals (disposable)	\$21
	Total for da Vinci instrument items	\$1608 [#]
Maintenance cost		\$778**
Total (= Cost/one-RATS case operation)		\$6850***

Table 1A shows the cost for the dVSi operation on the assumption of 100 cases in one institution per year with the projected JNHIS reimbursement system.

Table 1B Tentative calculation for the basis of costs associated with RATS for institutions which perform the dVSi Single Console procedures 100–300 times in a year

- \$2,480,000 (purchase price of the da Vinci Si Single Console) $\times$ 0.9 = \$2,232,000 (repayment cost)
\$2,232,000/5 year (service life) = \$446,400/year (repayment cost/year)
\$446,400/100 times (annual use) = \$4464* (repayment cost/operation)
 - Amount of maintenance cost
\$108,000/year (First year free) $\times$ 4 year/5 year = \$86,400/year
\$86,400/year $\times$ 0.9 = \$77,760/year (maintenance cost/year)
\$77,760/100 times (annual use) = \$778/year** (running cost/operation)
- For one-RATS case operation = repayment cost/operation (\$4464*) + medical materials cost/operation (\$1608[#]) + running cost/operation (\$778**) = **\$6850***/operation**

*repayment cost/operation, **running cost/operation, ***cost/one-robotic case operation, [#]medical materials cost for the dVSi/operation. Japanese national guidelines for the calculation of the costs of advanced medical care.¹⁸⁾ Table 1B shows a tentative calculation for the basis of costs associated with robotic medical care for institutions which perform the dVSi procedures 100 times. dVSi: da Vinci Surgical System Si; RATS: robotic-assisted thoracic surgery; JNHIS: Japanese National Health Insurance System

dVSi operation on the assumption of 100 cases in one institution/year with the projected JNHIS reimbursement system; equipment fee (\$4687 in 2012 reduced to \$4464 in 2014), medical materials costs (\$2860 in 2012 reduced to \$1608 in 2014), and maintenance cost (\$1800 in 2012 reduced to \$518 in 2014, and raised to \$778 again from January 2016 by Intuitive Surgical) (Table 1A).⁶⁾ In institutions in which the total of all operation using dVSi is more than 100 a year, the cost required per RATS procedure was reduced from \$6590 since October in 2014, and raised to \$6850 again from January 2016 (Table 1B). JNHIS reimbursement is based on the number of insurance points awarded for a given procedure or equipment used. The difference of costs for dVSi surgery in Table 2 varies based on the assumption of procedures performed between 100 (A), 150 (B), 200 (C), or 300 (D) per year at a single institution.

RALP now receives insurance reimbursement under the category of use of support devices for endoscopic surgery (\$5420 since April 2012) and RAPN also receives reimbursement for use of support devices for endoscopic surgery (\$3485 since April 2016). If the same standard amount were to be applied to various diseases in the field of general thoracic surgery, the additional cost for RATS, which would also require the set-up of support devices for endoscopic surgery would either be \$5420, which is the same as RALP, or \$3485, that is, the same as RAPN in the JNHIS paradigm of April 2016, which is based on the cost of the open thoracotomy approach.

We compared the costs for RATS and VATS, as decreed by the JNHIS (Table 3). Table 3 shows the comparison of medical expenses classified by operation method, based on the assumption of 100 cases in one institution per year after the dVSi price revision.

Table 2 Japanese national guidelines for the calculation of the costs of advanced medical care

\$1 = 100 yen on September 2016

➤ \$2,480,000 (purchase price of the dVSi Single) × 0.9 = \$2,232,000 (repayment cost)	
\$2,232,000/5 year (service life) = \$446,400/year (repayment cost/year)	
At an institution which perform the dVS operation A: 100, B: 150, C: 200, and D: 300 times in a year.	
A: \$446,400/100 times (annual use) = \$4464 (repayment cost/operation)	
B: \$446,400/150 times (annual use) = \$2976 (repayment cost/operation)	
C: \$446,400/200 times (annual use) = \$2,232 (repayment cost/operation)	
D: \$446,400/300 times (annual use) = \$1488 (repayment cost/operation)	
➤ Amount of maintenance cost: \$108,000/year × 4 year/5 year = \$86400/year	
\$86400/year × 0.9 = \$77760/year (maintenance cost/year)	
A: \$77760/100 times (annual use) = \$778/year (running cost/operation)	
B: \$77760/150 times (annual use) = \$519/year (running cost/operation)	
C: \$77760/200 times (annual use) = \$389/year (running cost/operation)	
D: \$77760/300 times (annual use) = \$259/year (running cost/operation)	
Pattern A: \$1608 (medical materials cost/operation) + \$778 (running cost/operation) + \$4464 (repayment cost/operation) = \$6850/one-RATS case operation	
Pattern B: \$1608 (medical materials cost/operation) + \$519 (running cost/operation) + \$2976 (repayment cost/operation) = \$5103/one-RATS case operation	
Pattern C: \$1608 (medical materials cost/operation) + \$389 (running cost/operation) + \$2232 (repayment cost/operation) = \$4229/one-RATS case operation	
Pattern D: \$1608 (medical materials cost/operation) + \$259 (running cost/operation) + \$1488 (repayment cost/operation) = \$3355/one-RATS case operation	

Table 2 shows a tentative calculation for the basis of costs associated with robotic medical care for institutions which perform the dVSi procedures 100 times (pattern A), 150 times (pattern B), 200 times (pattern C), and 300 times (pattern D) in a year, respectively. dVSi: da Vinci Surgical System Si; RATS: robotic-assisted thoracic surgery

Table 3 Comparison of the medical expense classified by operation-method under the JNHIS after price revision of dVS since April 2016

Procedure		Change in cost of procedures performed in Japan			
		Excluding robot		Including robot (price of the Excluding robot + \$5420)	
		Benign	Malignant	Benign	Malignant
Thymectomy	Simple	\$3700	Simple \$3700	Simple thymectomy \$9120	Simple \$9120
	Extended (with MG)	Open \$3171 VATS \$5895	Extended \$5602	Extended thymectomy (with MG) \$8591 \$9120	Extended \$11022
Resection of mediastinal tumor	Open	\$3700			
	VATS	\$5895	\$5895		
Lobectomy	Open	\$5835	\$7264	\$11255	\$12684
	VATS	\$5895	\$9200		

Table 3 shows the cost for dVS-surgery for 100 robotic cases per year at one institution with the projected JNHIS reimbursement system in the same manner as for RALP. MG: myasthenia gravis; dVS: da Vinci Surgical System; VATS: video-assisted thoracic surgery; RALP: robotic-assisted laparoscopic prostatectomy; JNHIS: Japanese National Health Insurance System

Figures 1 and 2 show the difference between open thoracotomy procedures, VATS and RATS procedures, if institutions performed the dVSi operation 100, 150, 200, or 300 times per year, and the projected JNHIS additional insurance reimbursement for endoscopic surgery

(if the same as RALP: \$5420; and if the same as RAPN: \$3485). For extended thymectomy in cases with myasthenia gravis (**Fig. 1**), the anticipated reimbursement by the JNHIS (\$10,021) shows a price insufficiency (−\$1430 per procedure based on 100 times/year) calculated on the

Fig. 1 Cost of extended thymectomy with myasthenia gravis among open thoracotomy, VATS and RATS procedures. The financial differences are shown among institutions performing RATS procedures, in which institutions performed the dVSi operation 100, 150, 200, or 300 times per year. Figures are based on data contained in **Tables 1, 2, and 3**. Since the purchase price and 5-year service life cost are set by the government, the cost per RATS procedure in the institution obviously decreases with the number of procedures performed annually. MG: myasthenia gravis; VATS: video-assisted thoracic surgery; RATS: robotic-assisted thoracic surgery; dVSi: da Vinci Surgical System Si; RALP: robotic-assisted laparoscopic prostatectomy; RAPN: robotic-assisted partial nephrectomy

Fig. 2 Cost of pulmonary lobectomy for malignant disease among open thoracotomy, VATS and RATS procedures, in institutions which performed the dVSi operation 100, 150, 200, or 300 times in a year. Figures are based on data contained in **Tables 1, 2, and 3**. dVSi: da Vinci Surgical System Si; VATS: video-assisted thoracic surgery; RATS: robotic-assisted thoracic surgery; RALP: robotic-assisted laparoscopic prostatectomy; RAPN: robotic-assisted partial nephrectomy

basis of the projected reimbursement. However, institutions performing at least 150 procedures per year would show a positive CBP (\$317 per procedure) under the projected reimbursement system, as in the case of RALP. Be that as it may, when projected reimbursement is the same as for RAPN, those institutions performing at least 300 dVSi procedures per year attain a positive CBP level of only \$130 per procedure. The simulation of cost for pulmonary lobectomy (malignant disease) is shown in **Fig. 2**. The evaluation for CBP shows the same result with extended thymectomy in cases with myasthenia gravis (**Fig. 1**).

Discussion

Our series of studies enable cost–benefit analyses understandable to clinicians and leads to the reduction of medical costs which may finally pave the way for the extension of the benefits of robotic surgery to many more patients.⁶⁾ The governmental pricing of robotics will greatly influence the inclusion of this field in future medical treatment in Japan. The JNHIS has provided insurance coverage of all Japan since 1961. The medical copayment patients are liable for 30% of other medical expenses from paid by the government. The annual trend of medical costs to increase continues to be a focus of much political disagreement. Not only is the background complicated and affected by Japan's rapidly aging society, advanced medical developments, and the increasing cost of drugs are involved. In an effort to maximally limit the national health care financial burden, the government must always strive to improve, yet control the quality and costs of the medical insurance system. This in turn means that determining the costs of completely new techniques, such as robotic surgery, is always problematic.⁶⁾ With regard to the clinical hypothesis concerning robotics in Japan, no coherent final conclusion is attainable unless the number of RATS cases per institution increases. However, the high medical cost is the first practical issue that needs to be addressed to solve this clinical problem. In other words, the high cost limit procedures, which increases costs.⁶⁾ However, medical costs were reformed by the JNHIS in April 2016, and the support devices for endoscopic surgery for robotic surgery of prostate cancer insurance reimbursement amount was compared to the lower \$1935 in cases of renal cell carcinoma. The reasons for this are related to surgical difficulty, etc., but also to the somewhat related medical and economic backgrounds of

Japan are not independent factors. In many countries in which medical services are covered by health insurance, the increase in medical costs induced by robot surgery aims at the ultimate decrease in medical costs by shortening the length of hospitalization and reducing postoperative complications. It seems that decisions on the medical system of robotic surgery in the future require comprehensive investigations incorporating an overall view and comprehension of the medical system as a single integrated whole concept,^{1–6)} and it is essential for future stable development that the problem should be settled as soon as possible. It seems that the economic management in the unit institution is enabled if the dVS would be utilized in combination with urology, gynecology, and gastrointestinal surgery under the present Japanese conditions, that is, as shown in **Figs. 1** and **2**, if the rate of operation of the robot surgery cannot be accomplished unless 150–300 procedures are performed per single institution annually, it is expected that deficit cost feedback is impossible. Four following solutions are considered to approach the issue of medical cost of robot surgery; 1) basically the establishment of a medical service using a health insurance score, 2) further price reduction of various charges of dVS, etc., 3) a medical-specific district is established and a determinative mix of medical examinations and treatments (in using the organization of medical expenses outside the insurance) is approved, and 4) construction of a cheaper domestic robot.

However, the raising of the medical cost 1) cannot allow for what we consider the current Japanese financial status, 2) concerning views about price reduction of various charges of dVS has been reported in our previous paper.⁶⁾ In the Asian area (Japan/Korea) and American and European countries (USA/UK/Germany/France), the information about various expenses of dVS is different due to the varied many circumstances of each country. However, the reduction in the price of various instrumentations of dVS was performed in October 2014, and revised dVS came to be utilized. The reduction of dVS may be the most realistic solution among medical cost countermeasures when we consider such a background. Although it depends on the economic situation of the country, it seems that the initial purchase expense in the medical equipment helps reduce the cost in global standards. The reason is because the correction of the medical difference possibly leads to further medical technology development. If more medical equipment were introduced in the Asian area, there is potential

connection with industry, and diode and light-emitting diode (LED) technology would be involved. Concerning 3), regarding the plan about treatment partially covered by insurance, it seems that participation of TPP influences would be involved in the future. The global examination that assumes Japan and world medical technology cooperation is one that indicates this type of situation. Actually, we are basically involved in a system of public health insurance for the whole nation to support an aging society and, in Japan, have insurance medical administration system that is rare in the world performing medical care. The foundation of restrictive treatment partially covered by insurance may be one of the ways out, after having identified sufficient safety to support the Japanese future. If an advanced medical technology is beyond a range of the Japanese insurance system, it may be needed in future to establish special districts (or institutions) of medical special regions. In other words, consideration of the medical economic partial support based on the current system by establishing the area where advanced medical techniques were authorized restrictively. It seems that we can secure the safety of the medical level by limiting the verification medical facilities which can permit advanced medical technology. Point 4) seems the most important solution for the future of Japanese medical care in that the Japanese technology has a robust global potential. Therefore, completion of medical robotic technology made in Japan by collaboration with a research organization and company believing this concept as a fundamental solution is essential.

The medical technology that seems to be expanding in the world will not arrive at its destination as a developed medical care system, if we do not fix our eyes on the human future and prosperity above all (as was the case in penicillin and computed tomography). Robotic surgery is only a model of one of the fields of human technical information that will surge further in nature. In addition, new innovations those are not limited to robots for surgery as well as one company will be applied to medical care systems. However, we produce the results in which a medical gap occurs with a real issue by which an economic burden is borne by the risk for such an advanced medical care. It is proper that a company pursues benefit, but it is not appropriate that single Japanese, or other medical care organization should aim to force the patient to assume an unrealistic economic burden. Improvement and productivity of robot technology will rise before long, and the future when a robot product is offered at a very low cost will come. This may be partly cost by

the JNHIS coverage of the induction of robot surgery. Induction of legal maintenance or the medical economic system throughout the world cannot help but spread advanced technology. One of the problems in Japan, China, and Korea is the high price of the equipment, resulting from the limited number of manufacturers in the field, notably among which has been Intuitive Surgical Inc., the manufacturer of the dVS system.⁶⁾ As time passes and patents expire, a greater range of products, with resulting heightened competition and lower prices should help alleviate the present situation. For RAS to make greater strides and gain widespread use, at present costs a single institution in Japan must be able to perform 150 cases annually, which few institutions are willing to commit to. Thus, the future development of the dissemination of RAS techniques and education are inexorably linked with economics. Less costly equipment is essential for the benefits of RAS to permeate to the public.

Conclusion

Robotic surgery in some areas receives insurance reimbursement for its “supportive” use for endoscopic surgery as for RALP and RAPN. However, at present, it is necessary to perform dVSi surgery at least 150–300 times in a year in a given institution to prevent a deficit in income.

In the present condition, always keeping medical economics in mind, we must maintain a system which is relatively unaffected by cost and reasonable med-tech development made in Japan by medical mechanic cooperation.

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Disclosure Statement

The authors and editor declare that they have no conflicts of interest associated with this study.

References

- 1) Paul S, Jalbert J, Isaacs AJ, et al. Comparative effectiveness of robotic-assisted vs thoracoscopic lobectomy. *Chest* 2014; **146**: 1505-12.
- 2) Swanson SJ, Miller DL, McKenna RJ, et al. Comparing robot-assisted thoracic surgical lobectomy with conventional video-assisted thoracic surgical lobectomy and wedge resection: results from a multihospital database (Premier). *J Thorac Cardiovasc Surg* 2014; **147**: 929-37.
- 3) Nasir BS, Bryant AS, Minnich DJ, et al. Performing robotic lobectomy and segmentectomy: cost, profitability, and outcomes. *Ann Thorac Surg* 2014; **98**: 203-8; discussion 208-9.
- 4) Deen SA, Wilson JL, Wilshire CL, et al. Defining the cost of care for lobectomy and segmentectomy: a comparison of open, video-assisted thoracoscopic, and robotic approaches. *Ann Thorac Surg* 2014; **97**: 1000-7.
- 5) Barbash GI, Glied SA. New technology and health care costs—the case of robot-assisted surgery. *N Engl J Med* 2010; **363**: 701-4.
- 6) Kajiwaru N, Patrick Barron J, Kato Y, et al. Cost-benefit performance of robotic surgery compared with video-assisted thoracoscopic surgery under the Japanese National Health Insurance System. *Ann Thorac Cardiovasc Surg* 2015; **21**: 95-101.
- 7) Japan Robotic Surgery Society (<http://j-robo.or.jp/index.html>).
- 8) Rückert JC, Swierzy M, Ismail M. Comparison of robotic and nonrobotic thoracoscopic thymectomy: a cohort study. *J Thorac Cardiovasc Surg* 2011; **141**: 673-7.
- 9) Marulli G, Rea F, Melfi F, et al. Robot-aided thoracoscopic thymectomy for early-stage thymoma: a multicenter European study. *J Thorac Cardiovasc Surg* 2012; **144**: 1125-30.
- 10) Marulli G, Schiavon M, Perissinotto E, et al. Surgical and neurologic outcomes after robotic thymectomy in 100 consecutive patients with myasthenia gravis. *J Thorac Cardiovasc Surg* 2013; **145**: 730-5; discussion 735-6.
- 11) Park BJ, Melfi F, Mussi A, et al. Robotic lobectomy for non-small cell lung cancer (NSCLC): long-term oncologic results. *J Thorac Cardiovasc Surg* 2012; **143**: 383-9.
- 12) Kent M, Wang T, Whyte R, et al. Open, video-assisted thoracic surgery, and robotic lobectomy: review of a national database. *Ann Thorac Surg* 2014; **97**: 236-42; discussion 242-4.
- 13) Kajiwaru N, Kakiwana M, Usuda J, et al. Extended indications for robotic surgery for posterior mediastinal tumors. *Asian Cardiovasc Thorac Ann* 2012; **20**: 308-13.
- 14) Kajiwaru N, Taira M, Yoshida K, et al. Early experience using the da Vinci Surgical System for the treatment of mediastinal tumors. *Gen Thorac Cardiovasc Surg* 2011; **59**: 693-8.
- 15) Kajiwaru N, Kakiwana M, Kawate N, et al. Appropriate set-up of the da Vinci Surgical System in relation to the location of anterior and middle mediastinal tumors. *Interact Cardiovasc Thorac Surg* 2011; **12**: 112-6.
- 16) Kajiwaru N, Akata S, Hagiwara M, et al. High-speed 3-dimensional imaging in robot-assisted thoracic surgical procedures. *Ann Thorac Surg* 2014; **97**: 2182-4.
- 17) Kajiwaru N, Maeda J, Yoshida K, et al. Maximizing use of robot-arm no. 3 in daVinci-assisted thoracic surgery. *Int Surg* 2015; **100**: 930-3.
- 18) Summary of advanced medical care; Home page of the Ministry of Health, Labour and Welfare of Japan. (in Japanese)