Surgery versus percutaneous transcatheter embolization for pulmonary arteriovenous malformation: Analysis of a national inpatient database in Japan

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ABSTRACT

Objective: Although the treatment options for pulmonary arteriovenous malformation are surgery and percutaneous transcatheter embolization, no study has compared the outcomes between these 2 treatments.

Methods: From the Japanese Diagnosis Procedure Combination database, the medical records of 996 patients who received treatment for pulmonary arteriovenous malformation between 2010 and 2015 were retrospectively reviewed. We created balanced groups for surgery or percutaneous transcatheter embolization using propensity scoring. The primary outcome was the rate of reintervention for pulmonary arteriovenous malformation, and the secondary outcomes were composite complications and postoperative length of stay. Patients who had any 1 of the complications during hospitalization were considered to have experienced a composite complication.

Results: Of the total sample, 211 patients underwent surgery and 785 patients underwent percutaneous transcatheter embolization. By using 1-to-1 propensity score matching, 202 pairs were selected. Compared with percutaneous transcatheter embolization, surgery was associated with a significantly higher proportion of composite complications (6.9% vs 2.0%, $P = .027$) and longer postoperative length of hospital stay (median, 6 vs 2 days, $P < .01$). However, surgery resulted in a significantly lower rate of reintervention for pulmonary arteriovenous malformation (2.1% vs 8.3% at 2 years; $P < .01$).

Conclusions: Percutaneous transcatheter embolization had the advantage in composite complications and shorter postoperative length of stay compared with surgery, but surgery had higher curability than percutaneous transcatheter embolization. Surgery may be considered as a therapeutic option for patients with lesions that can be completely resected and are difficult to treat with percutaneous transcatheter embolization. (J Thorac Cardiovasc Surg 2017;154:1137-43)

The rate of reintervention in patients with PAVM.

Central Message

PTE for PAVM is superior to surgery in composite complications and length of stay, but surgery is more likely to be definitive.

Perspective

This study is the first report comparing the outcomes of surgery versus PTE for PAVM in a large cohort of patients. Surgery can be considered as an alternative for patients with lesions that would be completely resectable and difficult to treat with PTE.

See Editorial Commentary page 1144.

Pulmonary arteriovenous malformation (PAVM) is a rare malformation that connects a pulmonary artery to a pulmonary vein, bypassing the normal pulmonary capillary bed and resulting in an intrapulmonary right-to-left shunt.

The first description of PAVM was reported by Churton in 1897,¹ and multiple case series have been published since then. It causes various complications, including dyspnea on exertion, cerebrovascular accidents, and life-threatening pulmonary hemorrhage.^{2,3}

Surgery had been the only treatment for PAVM until the 1980s, but since then, percutaneous transcatheter embolization (PTE) has become the most commonly used treatment

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Scanning this QR code will take you to a supplemental video for the article.

Abbreviations and Acronyms

DPC	=	Diagnosis Procedure Combination
HHT	=	hereditary hemorrhagic telangiectasia
ICD-10	=	International Classification of Diseases, Tenth Revision
PAVM	=	pulmonary arteriovenous malformation
PTE	=	percutaneous transcatheter embolization
VATS	=	video-assisted thoracic surgery

for patients with PAVM. Surgery is largely reserved for cases not amenable to embolization.⁴ The advantages of embolization over surgery are that it is less invasive and easy to repeat, if necessary. However, evidence supporting PTE is based only on the results of a retrospective, uncontrolled, observational case series and has not been directly compared with surgery.⁵ In addition, surgeons began using video-assisted thoracic surgery (VATS) in the 1990s, and some previous studies have shown good outcomes (Video 1). VATS is now commonly available even in nonacademic hospitals. Therefore, we hypothesized that surgery for PAVM would be as safe as PTE and more definitive. We aimed to compare the safety and efficacy of surgery and PTE for PAVM using data from a national, multicenter, large-scale database in Japan.

MATERIALS AND METHODS

Diagnosis Procedure Combination Database

This study was a retrospective population-based cohort study based on the Japanese Diagnosis Procedure Combination (DPC) database. The details of this database have been described by Matsuda and colleagues.⁶ In short, the DPC database includes data from admission/discharge abstracts and administrative claims for approximately 7 million inpatients per year from more than 1000 hospitals, accounting for 50% of all inpatient admissions to acute care hospitals in Japan. All 82 academic hospitals are obliged to contribute to the database, but the participation of community hospitals is voluntary. The database includes the following information: unique identifiers of hospitals; patient age and sex; body height and weight; type of admission (scheduled or unscheduled); main diagnoses, comorbidities and symptoms that were already present at admission, and complications that occurred after admission, recorded using the International Classification of Diseases, Tenth Revision (ICD-10) codes; therapeutic procedures coded by the Japanese original K-code; postoperative length of stay; and in-hospital death. Attending physicians are required to record the main diagnoses, comorbidities, symptoms present at admission, and complications that occurred after admission using ICD-10 codes. The DPC database clearly differentiates the comorbidities on admission from the complications during hospitalization. To optimize the accuracy of the data, the attending physicians are responsible to record the diagnoses with reference to the medical charts. The DPC database is not publicly available. This study was approved by the Institutional Review Board of the University of Tokyo. The requirement for informed consent was waived because of the anonymous nature of the data used in this study.

Patient Selection and Data

We identified patients who were diagnosed with PAVM (ICD-10 code, I28.0) as the main diagnosis and who underwent surgery (DPC procedure

VIDEO 1. Thoroscopic wedge resection of PAVM located in the left lower lobe. Video available at: [http://www.jtcvsonline.org/article/S0022-5223\(17\)31047-4/addons](http://www.jtcvsonline.org/article/S0022-5223(17)31047-4/addons).

code K511 and K513) or PTE (K615) from July 1, 2010, to March 31, 2015. We divided the eligible patients into surgery and PTE groups on the basis of the initial procedure to treat PAVM. The following details were recorded: patient age and sex, body mass index, Elixhauser comorbidities, type of hospital (academic or nonacademic), type of admission, hospital bed size, year of intervention, and findings suggestive of symptoms of PAVM on admission. The Elixhauser comorbidity measure encompasses 31 medical conditions and is believed to be a reliable predictor model for postoperative outcomes.⁷⁻⁹ Quan and colleagues¹⁰ algorithms for Elixhauser comorbidities using ICD-10 codes were used in this study. Symptoms on admission included chronic heart failure (ICD-10 code, I50), cerebral infarction (I63 and I64), brain abscess (G060), transient ischemic attack (G459 and I678), pulmonary hypertension (I270 and I272), hemoptysis (R042), hemothorax (J942), pulmonary insufficiency (J960, J961, and J969), and dyspnea (R060).

Outcome Measures

The main outcome measure of this analysis was the rate of reintervention. The secondary outcomes were composite complications and postoperative length of stay. During the study period, we identified patients who were readmitted to the same hospital where the initial treatment had been done. Reintervention for PAVM was defined as any second treatment (surgery or PTE) for PAVM performed after the initial treatment during the same hospitalization or readmission to the same hospital. The interval from the initial procedure to reintervention was calculated. Composite complications included (1) in-hospital death and (2) complications, including pneumonia (J12-18), wound infection (T793, T813, and T814), pulmonary infarction (I269), pleural effusion (J90 and J91), atelectasis (J981), acute renal failure (N17), cerebral infarction (I63 and I64), myocardial infarction (I20-24), and atrial fibrillation (I48 and I978). Patients who experienced any 1 of these events were considered to have experienced a composite complication. The most widely acknowledged advantage for considering the use of composite complications is to reduce the sample size requirement and increase the statistical efficiency by raising the observed event proportion.^{11,12} Postoperative length of stay was defined as the period from the day of treatment to the day of discharge. If a patient had multiple admissions during this study period, we added each postoperative length of stay to calculate the total time of postoperative stay.

Statistical Analysis

To adjust for measured confounding factors, we performed propensity score matching between the surgery group and the PTE group.¹³ Propensity

scores were calculated using a logistic regression model for the receipt of surgery as a function of the following patient conditions and hospital factors: patient age, sex, body mass index, Elixhauser comorbidities with more than 0.5% prevalence in the cohort, type of hospital, type of admission, hospital bed size, year of intervention, and symptoms on admission. The C-statistic for evaluating good fit was calculated. Each patient in the surgery group was matched with a patient in the PTE group who had the closest estimated propensity score within a specified range (<0.2 of the pooled standard deviation of the estimated logits).¹⁴ To describe patient demographic data, categorical variables were summarized as the number and proportion, and continuous variables were summarized as the mean and standard deviation. We compared patient demographic data between the surgery group and the PTE group in the unmatched and propensity score-matched groups using standardized difference.¹⁴

We used the Fisher exact test or Pearson's chi-square test to compare the proportions of each complication, in-hospital death, and composite complication. Postoperative length of stay was right-skewed and therefore analyzed using the nonparametric Mann-Whitney *U* test. Cumulative incidence curves of reintervention were estimated using the Kaplan-Meier method and compared between the 2 groups using the log-rank test. All statistical analysis was performed using IBM SPSS version 22.0 (IBM Corp, Armonk, NY).

RESULTS

We identified 996 patients who received initial treatment for PAVM during the study period. Five patients who underwent both surgery and PTE during the same hospitalization were included for analysis on an intention-to-treat bias. We divided the eligible patients into surgery and PTE groups on the basis of the initial procedure to treat PAVM; 211 patients (21.1%) underwent surgery and 785 patients (78.8%) underwent PTE. In the surgery group, 200 patients (94.7%) were treated by VATS. By using 1-to-1 propensity score matching, 202 pairs were selected. The C-statistic for good fit was 0.704, and the mirrored histogram showed good distribution of the covariates (Figure 1).

Table 1 shows the patient characteristics in the unmatched and propensity score-matched groups. In the unmatched group, patients with a younger age, chronic heart failure, hemoptysis, and treatment in academic hospitals were more likely to undergo PTE, whereas patients with hypertension were more likely to undergo

FIGURE 1. Graph of propensity scores in the surgery group (blue bars) and the percutaneous transcatheter group (green bars) after propensity score matching. PTE, Percutaneous transcatheter embolization.

surgery. After propensity score matching, the distributions of patient backgrounds were closely balanced between the 2 groups.

Table 2 presents the outcomes of surgery versus PTE in the propensity score-matched groups. Patients in the surgery group had a significantly higher proportion of composite complications (6.9% vs 2.0%, $P = .027$), although the occurrence of each complication and in-hospital death were low in both the groups and not significantly different. Postoperative length of stay was significantly longer in the surgery group than in the PTE group (median, 6.0 days, interquartile range, 4.0-8.0 days vs median, 2.0 days, interquartile range, 2.0-5.0 days, $P < .01$). We also analyzed the total time of postoperative stay and obtained the same result (median, 6.0 days, interquartile range, 4.0-8.0 days vs median, 2.5 days, interquartile range, 1.0-5.0 days, $P < .01$).

Figure 2 shows the cumulative incidence curves of reintervention in the 2 groups. The median follow-up time was 23.4 months in the surgery group and 19.4 months in the PTE group. In the surgery group, the number of patients at risk was 124 at 18 months and 59 at 36 months. In the PTE group, 108 were at risk at 18 months and 52 at 36 months. Patients who underwent surgery had lower rates of reintervention compared with those who underwent PTE (2.1% vs 8.3% at 2 years), and the difference was significant ($P < .01$).

DISCUSSION

Composite complications, which included in-hospital death, pneumonia, wound infection, pulmonary infarction, pleural effusion, atelectasis, acute renal failure, cerebral infarction, myocardial infarction, and atrial fibrillation, were significantly higher in the surgery group, and the postoperative length of stay was significantly longer in the surgery group than in the PTE group. In contrast, the rate of reintervention was lower in the surgery group than in the PTE group.

The present study showed that PTE was superior to surgery in terms of composite complications and postoperative length of stay. VATS has been proven to be safe and feasible even for major pulmonary resections, with good functional results, less morbidity, and improved quality of life compared with conventional open approaches.¹⁵⁻¹⁷ Some previous reports showed that surgery of patients with PAVM by VATS also had good outcomes.¹⁸⁻²⁰ In our study, more than 90% of patients in the surgery group underwent VATS. Each complication and in-hospital death were low in both groups, but patients undergoing surgery had a higher proportion of composite complications in the propensity score-matched analysis. Our findings indicated that PTE may still have some advantages in terms of safety. The PTE group had shorter postoperative length of stay compared with the surgery group, and the analysis of the

TABLE 1. Characteristics of patients with pulmonary arteriovenous malformation

	Full sample			Matched		
	Surgery (n = 211)	PTE (n = 785)	Standardized difference	Surgery (n = 202)	PTE (n = 202)	Standardized difference
Age (y), mean	54.6	52.7	0.104	54.3	54.5	−0.011
Age category, n (%)						
≤20 y	9 (4.3)	58 (7.4)	−0.134	9 (4.5)	12 (5.9)	−0.067
21-40 y	35 (16.6)	143 (18.2)	−0.043	35 (17.3)	29 (14.4)	0.081
41-60 y	76 (36.0)	237 (30.2)	0.124	70 (34.7)	75 (37.1)	−0.052
61-80 y	85 (40.3)	329 (41.9)	−0.033	82 (40.6)	77 (38.1)	0.051
≥81 y	6 (2.8)	18 (2.3)	0.035	6 (3.0)	9 (4.5)	−0.079
Gender						
Male, n (%)	45 (21.3)	193 (24.6)	−0.078	43 (21.3)	41 (20.3)	0.024
Female, n (%)	166 (78.7)	592 (75.4)	0.078	159 (78.7)	161 (79.7)	−0.024
BMI, mean	21.9	21.7	0.058	21.9	21.8	0.031
BMI category, n (%)						
≤18.5	28 (13.3)	132 (16.8)	−0.099	27 (13.4)	26 (12.9)	0.015
18.5-23	116 (55.0)	377 (48.0)	0.139	111 (55.0)	112 (55.4)	−0.010
23-25	30 (14.2)	117 (14.9)	−0.019	29 (14.4)	32 (15.8)	−0.041
25-30	30 (14.2)	110 (14.0)	0.006	29 (14.4)	27 (13.4)	0.029
≥30	6 (2.8)	16 (2.0)	0.052	5 (2.5)	3 (1.5)	0.071
Elixhauser comorbidities, n (%)						
Cardiac arrhythmias	6 (2.8)	14 (1.8)	0.071	5 (2.5)	5 (2.5)	0.000
Valvular disease	5 (2.4)	11 (1.4)	0.071	4 (2.0)	3 (1.5)	0.038
Peripheral vascular disorders	1 (0.5)	4 (0.5)	−0.005	1 (0.5)	0 (0)	0.100
Hypertension	25 (11.8)	55 (7.0)	0.166	22 (10.9)	17 (8.4)	0.084
Paralysis	1 (0.5)	4 (0.5)	−0.005	1 (0.5)	0 (0)	0.100
Other neurologic disorders	5 (2.4)	8 (1.0)	0.105	4 (2.0)	3 (1.5)	0.038
Chronic pulmonary disease	12 (5.7)	30 (3.8)	0.088	10 (5.0)	6 (3.0)	0.102
Diabetes (uncomplicated)	9 (4.3)	25 (3.2)	0.057	8 (4.0)	7 (3.5)	0.026
Diabetes (complicated)	3 (1.4)	5 (0.6)	0.078	3 (1.5)	3 (1.5)	0.000
Hypothyroidism	3 (1.4)	4 (0.5)	0.093	2 (1.0)	3 (1.5)	−0.045
Liver disease	4 (1.9)	15 (1.9)	−0.001	4 (2.0)	3 (1.5)	0.038
Peptic ulcer disease	6 (2.8)	13 (1.7)	0.080	4 (2.0)	4 (2.0)	0.000
Solid tumor without metastasis	8 (3.8)	19 (2.4)	0.079	7 (3.5)	5 (2.5)	0.058
Rheumatoid arthritis/collagen vascular diseases	2 (0.9)	10 (1.3)	−0.031	2 (1.0)	2 (1.0)	0.000
Deficiency anemia	5 (2.4)	13 (1.7)	0.051	5 (2.5)	4 (2.0)	0.034
Hospital						
Academic, n (%)	73 (34.6)	458 (58.3)	−0.490	73 (36.1)	67 (33.2)	0.062
Nonacademic, n (%)	138 (65.4)	327 (39.2)	0.490	129 (63.9)	135 (66.8)	−0.062
Admission						
Scheduled, n (%)	207 (98.1)	772 (98.3)	−0.018	198 (98.0)	200 (99.0)	−0.082
Emergency, n (%)	4 (1.9)	13 (1.7)	0.018	4 (2.0)	2 (1.0)	0.082
No. of hospital beds						
≤299	8 (3.8)	30 (3.8)	−0.002	8 (4.0)	9 (4.5)	−0.025
300-599	108 (51.2)	259 (33.0)	0.375	102 (50.5)	98 (48.5)	0.040
600-899	57 (27.0)	289 (36.8)	−0.211	56 (27.7)	55 (27.2)	0.011
900-1199	28 (13.3)	166 (21.1)	−0.210	28 (13.9)	29 (14.4)	−0.014
≥1200	2 (0.9)	21 (2.7)	−0.130	2 (1.0)	1 (0.5)	0.058
Year						
2010	14 (6.6)	54 (6.9)	−0.010	14 (6.9)	10 (5.0)	0.084
2011	37 (17.5)	114 (14.5)	0.082	35 (17.3)	32 (15.8)	0.040
2012	48 (22.7)	171 (21.8)	0.023	46 (22.8)	47 (23.3)	−0.012
2013	49 (23.2)	181 (23.1)	0.004	45 (22.3)	38 (18.8)	0.086
2014	53 (25.1)	214 (27.3)	−0.049	52 (25.7)	61 (30.2)	−0.099
2015	10 (4.7)	51 (6.5)	−0.076	10 (5.0)	14 (6.9)	−0.084

(Continued)

TABLE 1. Continued

	Full sample			Matched		
	Surgery (n = 211)	PTE (n = 785)	Standardized difference	Surgery (n = 202)	PTE (n = 202)	Standardized difference
Comorbidities on admission						
At least 1 comorbidity, n (%)	20 (9.5)	91 (11.6)	−0.07	19 (9.4)	17 (8.4)	0.035
Chronic heart failure, n (%)	4 (1.9)	32 (4.1)	−0.13	4 (2.0)	2 (1.0)	0.082
Cerebral infarction, n (%)	9 (4.3)	29 (3.7)	0.03	8 (4.0)	9 (4.5)	−0.025
Brain abscess, n (%)	3 (1.4)	10 (1.3)	0.01	3 (1.5)	3 (1.5)	0.000
Transient ischemic attack, n (%)	1 (0.5)	3 (0.4)	0.01	1 (0.5)	0 (0)	0.100
Pulmonary hypertension, n (%)	1 (0.5)	4 (0.5)	−0.01	1 (0.5)	1 (0.5)	0.000
Hemoptysis, n (%)	1 (0.5)	14 (1.8)	−0.12	1 (0.5)	1 (0.5)	0.000
Hemothorax, n (%)	1 (0.5)	1 (0.1)	0.06	1 (0.5)	1 (0.5)	0.000
Pulmonary insufficiency, n (%)	4 (1.9)	13 (1.7)	0.02	4 (2.0)	2 (1.0)	0.082
Dyspnea, n (%)	1 (0.5)	1 (0.1)	0.06	1 (0.5)	1 (0.5)	0.000

PTE, Percutaneous transcatheter malformation; BMI, body mass index.

total time of postoperative stay showed the same result, which not only may be related to the lower proportion of composite complications in PTE but also may be strongly associated with the healthcare system in Japan. Most hospitals in Japan provide both early postoperative care and subsequent nursing care within a single hospitalization, whereas hospitals in the United States often quickly discharge patients to home or to rehabilitation centers. The Organization for Economic Co-operation and Development in 2016 showed that the national average length of hospital stay in acute care hospitals in Japan is 17.2 days, whereas that in the United States is only 5.4 days.²¹ Patients who undergo surgery in Japan tend to be in the hospital longer postoperatively, and this most likely affected the significant difference of postoperative length of hospital stay in the 2 groups.

Surgery had a high certainty of eliminating the fistula on the first treatment compared with PTE. Only 2.1% of patients in the surgery group required reintervention, whereas 8.3% of patients treated with PTE needed further treatment at 2 years. Major indications for treatment of PAVM are prevention of neurologic complications, including cerebral

infarction and abscess, improvement of exercise tolerance, and prevention of lung hemorrhage.⁵ Therefore, any PAVM more than 3 mm in size is considered for treatment regardless of the symptoms.^{22,23} Moreover, Pollak and colleagues³ insisted that smaller PAVM with a feeding artery of less than 3 mm has the benefit of protection against bacterial and paradoxical embolization. International guidelines for the diagnosis and management of hereditary hemorrhagic telangiectasia (HHT) in 2009 also suggested that targeting PTE to a feeding artery diameter as low as 2 mm may be appropriate.²⁴ Improvements in the tools available for treating PAVM have been made in parallel with developments in imaging technology. However, PAVM recanalization and collateralization after PTE are reported in the range of 5% to 19% of cases.^{3,25} Embolization of smaller vessels is technically difficult because they are harder to cannulate.²² On the other hand, large vessels are also difficult to occlude completely on the first PTE attempt, and the risk of insufficient embolization and recanalization is high, frequently resulting in reintervention.^{23,26} In our study, the surgery group had a significantly lower rate of reintervention than the PTE group, and it is possible that

TABLE 2. Outcome of surgery and percutaneous transcatheter embolization for pulmonary arteriovenous malformation

	Surgery (n = 202)	PTE (n = 202)	P value
Composite complication, n (%)	14 (6.9)	4 (2.0)	.027
In-hospital death, n (%)	3 (1.5)	0 (0)	.25
Complications			
Pneumonia, n (%)	3 (1.5)	1 (0.5)	.62
Wound infection, n (%)	1 (0.5)	1 (0.5)	1
Pulmonary infarction, n (%)	1 (0.5)	0 (0)	1
Pleural effusion, n (%)	2 (1.0)	0 (0)	.5
Atelectasis, n (%)	1 (0.5)	0 (0)	1
Acute renal failure, n (%)	0 (0)	1 (0.5)	1
Cerebral infarction, n (%)	2 (1.0)	1 (0.5)	1
Myocardial infarction, n (%)	2 (1.0)	0 (0)	.5
Atrial fibrillation, n (%)	1 (0.5)	1 (0.5)	1
Postoperative length of stay (d), median (IQR)	6 (4-8)	2 (2-5)	<.01

PTE, Percutaneous transcatheter malformation; IQR, interquartile range.

FIGURE 2. Kaplan–Meier cumulative incidence curve of reintervention received by patients with PAVM. The rate of reinterventions was lower in patients who received surgery (blue line) than in those initially treated with PTE (green line). PTE, Percutaneous transcatheter embolization.

surgery may be a good therapeutic option for these patients with lesions that can be completely resected and difficult to treat with PTE.

We analyzed approximately 1000 patients who underwent surgery or PTE for PAVM. The prevalence of PAVM has not been reported in the general population because it is a rare disorder and small PAVM is difficult to detect on chest x-rays. The incidence of HHT is estimated to be 13 to 20 per 100,000 among European, US, and Japanese populations,^{24,26,27} and PAVM has been reported in 30% to 50% of patients with HHT.^{28,29} On the basis of these data, the prevalence of PAVM associated with HHT is estimated as 5 to 10 per 100,000 and the total incidence of PAVM in the general population is estimated to be more. Given that the total population in Japan was estimated to be 127 million people in 2015, the number of treatments for PAVM (~200 patients per year) is acceptable. Most of the previously published studies were from single institutions, and only a few large studies including more than 100 cases have been reported because of the rarity of the disease.^{4,23} There has been no randomized controlled trial of treatment for PAVM, the current evidence for PTE being based on observational studies, nor have there been any comparative studies of surgery versus PTE for PAVM. In a Cochrane review, Hsu and colleagues⁵ mentioned that evidence from observational data alone cannot determine whether PTE is the most effective treatment for PAVM. However, they also stated that randomized controlled studies would not be feasible for ethical reasons and that it is unlikely that high-level evidence will become available in the near future. Therefore, large observational studies with detailed patient characteristics are required to compare the long-term results between

surgery and PTE. To the best of our knowledge, ours is the first report comparing the outcomes of surgery versus PTE for PAVM in a large cohort of patients, and it has important implications for the treatment of PAVM.

Approximately 90% of patients in this study were asymptomatic on admission. Because the use of chest computed tomography for screening and contrast echocardiography for diagnosing PAVM is becoming more common, it now tends to be detected incidentally at a smaller size.^{30,31} There is no definite guideline for the treatment of PAVM in Japan, but any PAVM more than 2 mm should be considered for treatment regardless of symptoms as mentioned earlier. This may be the reason for approximately 10% of patients in this study having any clinical evidence of symptoms that might have occurred as a result of PAVM. The 2 groups did not significantly differ for most such entities, although there were significantly more patients in the PTE group who had chronic heart failure or hemoptysis. This might be because PTE was preferred for these patients to avoid general anesthesia.

Study Limitations

First, the DPC database lacks detailed information about PAVM characteristics (vessel diameter, number, and location in the lung of the PAVM), the rate of patients with HHT, and preoperative lung function. These data are potentially related to the choice of treatment. Second, we could not assess the kind of surgery the patients underwent, the extent of loss of lung function after treatment, the grade of each complication, or the complications that occurred after discharge. These data would be important to compare the differences in results between the 2 groups in more detail. Third, the recorded diagnoses in the database may be less well validated than those in prospective studies because of possible misclassification or underreporting. For instance, only 0.5% patients in the surgery group had atrial fibrillation postoperatively in our study, and its proportion was relatively low compared with outcomes of lung resection by VATS in previous studies.¹⁶ However, we believe that the proportion of miscoding was relatively low in the database because the attending physicians recorded the diagnoses. Finally, we could not determine whether that was scheduled as part of the planned treatment. In addition, we could not detect any patients who underwent reintervention in a different hospital. Although few people would undergo reintervention at a hospital where the initial treatment was not done, it is possible that the rate of reintervention in this study might have been underestimated.

CONCLUSIONS

PTE for PAVM was superior to surgery in terms of composite complications and postoperative length of stay, but surgery had the provision of definitive treatment. Surgery

can be considered as an alternative for patients with lesions that are completely resectable and would be difficult to treat with PTE.

Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

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