

A Micro-Costing Analysis of Flexible Bronchoscopic Intubation in a Korean Tertiary Hospital

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Objectives: To evaluate the per-procedure cost of flexible bronchoscopic intubation in relation to the monetary value of the practice expense relative value units (RVUs) of the procedure. **Methods:** A micro-costing analysis of flexible bronchoscopic intubation was performed in the anesthesiology and pain medicine department of a Korean tertiary hospital over the fiscal year 2019. Cost records were collected and then categorized into three cost components: depreciation of reusable flexible bronchoscopes and video equipment, reprocessing, and repairs. The per-procedure cost was calculated by dividing the total annual cost by the annual number of flexible bronchoscopic intubations performed. The resulting per-procedure cost was then compared to the monetary value of the practice expense RVUs of the procedure. Considering that the annual procedural volume would significantly impact per-procedure costs and overall profitability, a deterministic sensitivity analysis (DSA) was conducted. **Results:** In total, 748 flexible bronchoscopic intubations were performed during the fiscal year. Total annual costs for depreciation of the bronchoscopes and video equipment, reprocessing, and repair were US\$ 31,921, US\$ 22,268, and US\$ 22,948 respectively. The calculated per-procedure cost of the flexible bronchoscopic intubation in the period was US\$ 103.1 while the fee listed in the fee schedule and the monetary value of the practice expense RVUs of the procedure were US\$ 69.9 and US\$ 52.2 respectively. Therefore, the procedure was performed at a loss over the period: the amount that the subject department lost with respect to the practice expense RVUs totaled as much as US\$ 38,039. The DSA demonstrated that the procedure would remain unprofitable even if twice the volume of procedures were performed over the same duration (n=1,500). **Conclusion:** The findings suggest that HIRA's determination of the practice expense RVUs of the procedure may have been underestimated and thus in need of review and recalculation to achieve adequate compensation. The per-procedure cost would vary by procedural volume and site of practice which indicates that a further multicenter study is required to confirm the study's findings.

Keywords Micro-costing; Practice expense; Fee-for-service; Relative value unit; Endoscope; Bronchoscope; Flexible bronchoscopic intubation.

Introduction

A bronchoscopy is a procedure that allows physicians to examine the lungs and airways, typically conducted by using a reusable flexible bronchoscope. It is frequently performed in several departments for the diagnosis of lung problems, bronchoalveolar lavage, bronchial wash, foreign-body management, or endotracheal intubation.¹⁾ Bronchoscopies are often performed by anesthesiologists to facilitate endotracheal intubation in patients with difficult airways (DA) and to place double-

lumen endotracheal tubes (DLT) in patients undergoing single-lung ventilation (SLV) procedures to establish airway access.^{2,3)} According to the Korean Healthcare Bigdata Hub, a national database of healthcare statistics, a total of 168,300 bronchoscopic procedures were performed in South Korea in 2019.⁴⁾

Among Korean healthcare professionals, it is firmly believed that fees for endoscopic procedures have been set far lower than their genuine cost.⁵⁾ As a result, these professionals have consistently requested adequate compensation for the procedures. While the fee for flexible bronchoscopic intubation was

determined by the Health Insurance Review and Assessment Service (HIRA) long time ago, the true costs are difficult for hospitals to clarify as there are multiple cost components associated with the procedure. Studies from the US, UK, France, Denmark, and Singapore have attempted to determine the cost of bronchoscopic procedures,⁶⁻¹⁰⁾ yet no similar data appears to be available in Korea.

The purpose of this study is to conduct a comprehensive micro-costing analysis of flexible bronchoscopic intubation, then evaluate the per-procedure cost and compare this to the monetary value of the practice expense relative value units (RVUs) of the procedure listed in the fee schedule.

In Korea, fee-for-service (FFS) has been the traditional health-care payment model where medical fees are fixed based on the fee schedule that is reassessed and released every year.¹¹⁾ Throughout the country, all the listed medical fees must be charged in accordance with the fee schedule regardless of whether they are operated by public or private organizations. This compensation system for medical services develops fees under the Korean Resource Based Relative Value Scale (K-RBRVS) and calculates them based upon the following three RVU components: physician work RVUs, practice expense RVUs, and malpractice expense RVUs.¹²⁾ This categorization is very similar to that of RBRVS in US Medicare,¹³⁾ because HIRA adopted their RBRVS based upon that of US Medicare.¹¹⁾ A major difference of note between systems of the two nations is that Korea currently utilizes a single-payer program.¹²⁾

At present HIRA only provides outdated information on the detailed composition of the total RVUs of listed procedures. Information regarding the detailed composition of the total RVUs of the listed procedures was released in 2008 following completion of the first relative value refinement project while details of the results of the second refinement project remained unavailable to the public as of Mar 2022. According to the judgment criteria service page on the HIRA website, the RVU total of the flexible bronchoscopic intubation was 563.09 which was determined through the first refinement project completed in 2005.¹¹⁾ Of the total of 563.09 RVUs, the physician work RVUs, practice expense RVUs and malpractice expense RVUs of the procedure were 135.05, 420.58, and 7.46 respectively. Among the RVU components, the practice expense component was the major part (74.7%).

A systematic literature search was conducted to identify precedent studies assessing the per-procedure cost of reusable bronchoscopes. Keyword searches were performed using the EMBASE database with a strategy combining Emtree, Embase subject headings, and the keywords “(bronchoscope OR fibroscope OR fibrescope OR ‘optical scopes’) AND cost AND ([article]/lim OR [article in press]/lim) AND [english]/lim AND [2011-2020]/py”, for articles published between January 1, 2011

and July 31, 2020. Our search was expanded to include articles published in Korean via RISS, a database maintained by the Korea Education and Research Information Service (KERIS).

Regarding eligibility criteria, only articles in English and Korean were included. Articles were identified and screened for eligibility by the author and a fellow researcher. Only those that covered costs of bronchoscope depreciation, costs of repair/maintenance of bronchoscopes and directly related video equipment, and costs of reprocessing of bronchoscopes were included. Any articles failing to cover these three cost components were excluded. Duplicate and irrelevant articles were removed from the list, and literature that did not address the primary data was also excluded.

Of the 95 articles retrieved, nine articles appeared to meet inclusion criteria and were reviewed in full. As one of these was written in French,¹⁰⁾ two did not include primary data for the studies,^{14,15)} and another did not include the three cost components, depreciation, repair/maintenance, and reprocessing.⁸⁾ Therefore, these four articles were excluded. Additionally, no Korean articles were discovered in the RISS database. The five selected articles matched the focus of the current study as they were single-center studies comparing the costs of single-use bronchoscopes and reusable bronchoscopes via a micro-costing analysis.^{6,16-19)}

Table 1 presents average costs per bronchoscopic procedure from the included studies. These studies were conducted at different times in various currencies, so their values were converted into US dollars (US\$) using conversion rates based on Purchasing Power Parities for meaningful comparison.²⁰⁾ The target price year was 2019 as this was the year cost data for the analysis was recorded. The statistical analysis revealed that the per-procedure cost estimates for reusable bronchoscopes ranged from US\$ 96.4 to US\$ 512.4. Average depreciation costs of US\$ 102.4, repair/maintenance costs of US\$ 83.7, and reprocessing costs of US\$ 58.5 resulted in a total average cost per procedure of US\$ 244.6.

Methods

Among the RVU components, the focus of this study was the practice expense RVU component which addresses costs of equipment, supplies, nonphysician staff costs and other resources utilized in a procedure.¹¹⁾ Since we had no way of determining the practice expense RVUs of the procedure in 2019, we assumed that its share remained the same (74.7%) in the 2019 fee schedule as the composition of the components which started to be applied since 2008.⁴⁾ Fees for procedures listed in the fee schedule are calculated by multiplying the total RVUs of a procedure by a conversion factor. The total RVUs of the flexible bronchoscopic intubation and the conversion factor for

Table 1. Statistical analysis of included articles

	Gupta et al. ⁶⁾	Tvede et al. ¹⁶⁾	McCahon et al. ¹⁷⁾	Perbet et al. ¹⁸⁾	Châteauevieux et al. ¹⁹⁾	Ave
Year of publication	2011	2012	2015	2017	2018	-
Original data year	2009	2009	2009–2014	2009–2014	2016	-
Location	US	DK	UK	FR	FR	-
Department	OR	OR/ICU	OR/ICU	ICU (BAL)	Global	-
No. of bronchoscopes	6	12	14	2	15	10
No. of annual procedures	166	360	141	76	1,644	477
Depreciation period (years)	15	10	7	5	6	9
Repair rate	1:55	N/A	1:18	N/A	N/A	-
Depreciation cost (US\$)*	23.8	142.6	213.4	111.9	20.5	102.4
Repair cost (US\$)*	63.2	37.6	219.6	68.4	29.5	83.7
Reprocessing cost (US\$)*	54.5	49.4	79.4	62.6	46.4	58.5
Cost per use (US\$)*	141.6	229.6	512.4	242.9	96.4	244.6

*PPP – adjusted²⁰⁾: the target price year was 2019. Ave, average; US, The United States; DK, Denmark; UK, The United Kingdom; FR, France; OR, operating room; ICU, intensive care unit; BAL, bronchoalveolar lavage; N/A, not available; PPP, Purchasing Power Parities

tertiary hospitals in 2019 were 1,088.5 RVUs, and KR₩ 74.9 respectively. As a result of the calculation, the fee for the procedure was roughly US\$ 69.9 in the year, we therefore assumed that the monetary value of the practice expense RVUs of the procedure was roughly US\$ 52.2.

The methodology used in this study was based upon those utilized in the previous studies. A micro-costing approach was used to quantify the per-procedure cost of flexible bronchoscopic intubations performed in the anesthesiology and pain medicine department of a Korean tertiary hospital located in the Seoul Metropolitan Area. With reference to the studies found in the literature review, cost records were collected and categorized into three main components: annual depreciation costs, repair costs, and reprocessing costs.^{6,16-19)}

Cost data associated with the flexible bronchoscopic intubations performed in the subject department over the fiscal year 2019, from January 1, 2019 to December 31, 2019, were obtained directly from the subject department, purchasing department, and biomedical engineering department, and then converted to US\$. The average exchange rate of KR₩ to US\$ in 2019 was US\$ 1=KR₩ 1,165.65 based on the conversion rate extracted from KEB Hana Bank on Jan 3, 2022. All cost data used in this study included value-added tax where applicable.

Regarding depreciation costs, the inputs were reusable bronchoscopes, and video equipment. Straight-line depreciation was used to estimate annual depreciation costs according to their respective depreciation periods. Although some of the precedent studies included automated endoscope reprocessors (AER) and storage supplies, i.e., drying cabinets, in the depreciation costs, this study considered these to be part of the reprocessing costs as they are closely related to reprocessing procedures. In terms of repair costs, out-of-pocket repair costs for reusable flexible bronchoscopes and related equipment

charged to the subject department were included. Finally, reprocessing cost inputs include those for the AER unit, drying cabinet, multi-use formulations, and labor utilization during reprocessing. The data on the annual number of bronchoscopes reprocessed, average reprocessing time, prices of related equipment, and multi-use formulations were thus obtained from the subject department. Additionally, the endoscope reprocessing personnel was interviewed to analyze the total turnaround time for reprocessing of reusable flexible bronchoscopes using high-level disinfection to calculate the average hands-on reprocessing time. The average hourly wage of nurses working in tertiary hospitals was estimated based on a Korean Health and Medical Personnel Survey published in 2019.²¹⁾ Pricing information about personal protective equipment (PPE) was unobtainable as the purchasing department deemed the information sensitive and refused to disclose figures. PPE costs were thus estimated upon information gleaned from interviews with PPE suppliers (Table 2).

Lastly, the per-procedure cost was calculated by adding the above-mentioned three cost components and dividing the result by the total number of flexible bronchoscopic intubations performed during the study period. The resulting per-procedure cost was then compared to the monetary value of the practice expense RVUs of the procedure listed in the fee schedule. Finally, a deterministic sensitivity analysis (DSA) was conducted to estimate per-procedure costs based on varying numbers of annual flexible bronchoscopic intubations with various procedure-to-repair ratios.

IRB review and approval were not required since this study did not involve human subjects.

Table 2. Parameter values and assumptions for the analysis

Category	Parameter	Value	Source
Procedures	FBI for DLT placements	738	ANES
	FBI for patients with DA	10	ANES
	Annual number of FBIs	748	Calculated
Fee for FBI	Fee in 2019* (US\$)	69.9	Calculated
	CF in 2019* (US\$)	0.06	HIRA
	Total RVUs in 2019	1,088	HIRA
	Share of the work RVUs	24.0%	HIRA
	Share of the PE RVUs	74.7%	HIRA
	Share of the malpractice RVUs	1.3%	HIRA
	Value of PE RVUs of FBI (US\$)	52.2	Assumption
Acquisition costs (US\$)	Bronchoscopes: 5 pcs	80,640	Purchasing dept.
	Video equipment: 2 pcs	25,205	Purchasing dept.
	AER: 1 pc	7,721	Purchasing dept.
	Drying cabinet: 1 pc	17,158	Assumption
Depreciation periods	Bronchoscopes (years)	3	HIRA
	Video equip. (years)	5	HIRA
	AER (years)	10	ANES
	Drying cabinet (years)	10	ANES
Reprocessing costs	High-level disinfectant (US\$)	151	Purchasing dept.
	Reuse period of disinfectant (days)	5	Olympus
	Number of uses per package	30	ANES
	Hourly wage for nurses (US\$)	17.9	Shin et al. ²¹⁾
	Avg. reprocessing time (hour)	0.67	ANES
	PPE cost per reprocessing (US\$)	4	Assumption
Repair costs	Number of repair cases in 2019	8	Bioengineering dept.
	Annual repair costs in 2019	22,948	Bioengineering dept.
	Repair ratio	94:1	Calculated
	Avg. repair cost (US\$)	2,868.5	Calculated

An exchange rate of US\$ 1 to KRW 1,165.65 is applied. *For secondary and tertiary hospitals. FBI, flexible bronchoscopic intubation; DLT, double lumen endotracheal tube; DA, difficult airway; ANES, anesthesiology and pain medicine department; CF, conversion factor; RVUs, relative value units; HIRA, Health Insurance Review & Assessment Service; PE, practice expense; AER, automated endoscope reprocessor; PPE, personal protective equipment

Results

The subject department performed a total of 748 cases of flexible bronchoscopic intubations during the analysis period, 738 DLT placements in patients undergoing SLV, and 10 flexible bronchoscopic intubations in patients with DA. The low number of flexible bronchoscopic intubations performed upon patients with DA indicates that these procedures were performed using substitute devices such as a Glidescope[®], a reusable video laryngoscope, rather than flexible bronchoscopes.

During the analysis period the department possessed five reusable flexible bronchoscopes and two pieces of video equipment. The gross acquisition cost of these bronchoscopes and associated equipment amounted to US\$ 105,845, with their respective depreciation periods being three and five years as determined by HIRA during the first refinement project. We therefore represented the annual depreciation of bronchoscopes

and video equipment as the acquisition costs divided by their depreciation periods. These calculations resulted in the annual depreciation cost of capital consumption across all the bronchoscopes and related video equipment of US\$ 31,921. Additionally, one AER unit and one drying cabinet housed in the department had a lifespan of 10 years. Given that the acquisition costs of the AER unit and drying cabinet were US\$ 7,721 and 17,158 respectively, the annual depreciation costs of these are US\$ 772 and US\$ 1,716 respectively (Table 3).

Regarding the cost of reprocessing, provided that the annual depreciation costs of the AER unit and cabinet were US\$ 772, and 1,716, and annual number of reprocessing cases was 748, the average costs per reprocessing of these items were roughly US\$ 1 and US\$ 2.3 respectively. The average cost of the high-level disinfectant (Acecide[®]) per reprocessing was US\$ 10.5, and the estimated cost of PPE per reprocessing was US\$ 4. In terms of labor costs, based on the relevant report,²¹⁾ the hourly

Table 3. Annual depreciation costs of acquired items

Item	Year of purchase	No.	Total price	Depreciation period	Annual depreciation costs*
Bronchoscope	2015–2019	5	80,640	3	26,880
Video equipment	2013–2019	2	25,205	5	5,041
AER [†]	2019	1	7,721	10	772
Drying cabinet [‡]	2014	1	17,158 [‡]	10	1,716

*Straight-line depreciation was used in the analysis; [†]The AER and cabinet were considered to be part of the reprocessing costs; [‡]Since the purchase record of the drying cabinet was not available during the data collection, we assumed the price was USD 17,158 with reference to one of the precedent studies.¹⁶⁾ AER, automated endoscope reprocessor

Table 4. Details of reprocessing costs

Item	Description	Cost (US\$)
Reprocessing costs	AER*	1.0
	Drying cabinet*	2.3
	High-level disinfectant	10.5
	PPE	4.0
	Labor	11.9
Cost per reprocessing		29.8

*Depreciation costs of the AER unit and drying cabinet were categorized as reprocessing costs because the main purpose of the items was endoscopy reprocessing. AER, automated endoscope reprocessor; PPE, personal protective equipment

wage for nurses working in tertiary hospitals was US\$ 17.9 in 2018 meaning US\$ 11.9 was spent on labor cost per reprocessing as the average hands-on time was 40 minutes. Combining these components, costs resulted in an estimated US\$ 29.8 spent per reprocessing making the gross cost of reprocessing US\$ 22,268 over the analysis period. A detailed description of the reprocessing costs is provided in Table 4.

In terms of repair costs, all the bronchoscopes, video equipment, AER units, and cabinets were the subject of routine maintenance conducted by the biomedical engineering department rather than via service contracts with the manufacturers. When major repairs were required, each instrument was returned to their manufacturers with out-of-pocket expenses then charged to the subject department. A total of eight repair incidents were recorded over the analysis period, resulting in an average ratio of 94:1 procedures to repairs. The total out-of-pocket expenses for the repairs came to US\$ 22,948 over the analysis period.

The total annual cost of flexible bronchoscopic intubations over the analysis period was thus US\$ 77,137. As 748 bronchoscopic intubations were performed, the average cost per procedure amounted to US\$ 103.1. Of this total, the largest proportion was accounted for by the combined depreciation costs of bronchoscopes and video equipment (41.4%), followed by repair (29.7%) and reprocessing (28.9%) costs. A detailed breakdown of the per-procedure cost is outlined in Table 5.

The per-procedure cost was therefore determined to be US\$ 103.1. Compared to the monetary value of the HIRA's practice expense RVUs of the procedure, US\$ 52.2 in 2019, this study reveals that the actual cost related to the RVU component was

nearly twice as much in the period. The HIRA's practice expense RVUs thus covered only 50.7% of its cost. Provided that HIRA estimates for the cost of the physician work and malpractice expense RVUs of the procedure were accurate, the subject department thus lost US\$ 50.9 per procedure during the analysis period. Furthermore, the amount lost by the subject department with respect to the practice expense RVU component of the procedure was as high as US\$ 38,039 during this time. The predetermined fee set by HIRA thus barely covered the actual cost of the procedure. Moreover, if the minor direct/indirect expenses which were not included in the cost analysis were included, the difference between the predetermined fee and actual cost would be far greater. Lastly, the average cost per use from the studies found in the literature review was more than twice as the per-procedure cost determined by this study. This may indicate that the missing part of this study might be bigger than we assumed.

The procedure-to-repair ratios found in two of the five articles in the literature review were 55:1, 18:1 respectively.^{6,17)} Compared to the 94:1 ratio determined by this study this marks a considerable difference. A DSA was thus conducted to assess the impact of parameter uncertainty on the cost analysis outcome. This was done by inputting two key parameters, the varying annual procedural volume, and various procedure-to-repair ratios.

Fig. 1 depicts variations in average bronchoscopic intubation costs from the volume of annual procedures at different procedure-to-repair ratios. Higher repair frequency positively correlates with the per-procedure cost at all procedure-to-repair ratios.

Discussion

Our study demonstrated that the compensation for the flexible bronchoscopic intubations performed by the subject department during the analysis period was insufficient to cover the associated costs. The procedures were thus performed at a loss. Given that costs associated with physician work and malpractice expense RVUs were fully compensated, this resulted in estimated annual losses totaling US\$ 38,039. These findings suggest that HIRA's determination of the practice expense RVUs

Table 5. Details of the per-procedure cost

Category	Item	Cost (US\$)	Sub-total (US\$)	Proportion (%)
Depreciation costs	Bronchoscopes	35.9	42.7	41.4
	Video equipment	6.7		
Reprocessing costs	AER	1.0	29.8	28.9
	Drying cabinet	2.3		
	Labor	11.9		
	High-level disinfectant	10.5		
	PPE	4.0		
Repair costs	Repair	30.7	30.7	29.7
Per-procedure cost		103.1		

AER, automated endoscope reprocessor; PPE, personal protective equipment

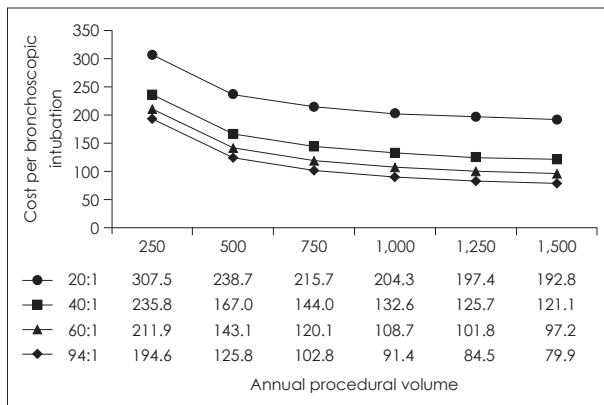


Fig. 1. Variations in per-procedure cost.

of the procedure may have been vastly underestimated and thus in need of review and recalculation to achieve adequate compensation. It is essential that costs of procedures are adequately compensated to avoid discouraging healthcare providers from purchasing the correct amount of equipment and delivering optimal care. Furthermore, the details of the second RVU refinement project must be made available for healthcare professionals to review. The information on the composition of the total RVUs of listed procedures in the fee schedule is not open to the public at the time of writing.

The results also indicate that the repair costs may have been underestimated to a great degree when HIRA determined the practice expense RVUs of the procedure since actual costs of repairs may be much greater in other hospitals provided that the procedure-to-repair ratio of this study was much lower (94:1) than those of the precedent studies, 18:1 and 55:1 respectively.^{6,17} As demonstrated in the sensitivity analysis, the per-procedure cost could total over three times the fee, resulting in a ratio of 1:20. Furthermore, maintenance costs were not included in the analysis.

Although the methodologies utilized in the articles found in the literature review varied to some degree, each conducted a micro-costing analysis.^{6,16-19} In terms of this study however, movement restrictions resulting from COVID-19 permitted

only limited hospital access, hindering our ability to conduct a thorough micro-costing analysis. The micro-costing analysis was thus conducted based upon limited primary cost data. Furthermore, the analysis is concerned primarily with the costs associated with the practice expense RVU component rather than physician work and malpractice expense RVU components. Despite this, the results do not include all items related to the practice expense RVUs of the procedure due to limitations encountered during the research period.

Due to limited time and resources, a single-center study was performed. The subject department of this research cannot be considered representative of all anesthesiology and pain medicine departments found in the 45 tertiary hospitals throughout the country. However, the results of this study are significant in that they can provide decision makers and other stakeholders with a deeper understanding of the differences between the current fee and the actual cost of the procedure. Furthermore, all the precedent studies found in the literature review were single-center studies.^{6,16-19} The result of this study also indicates that a per-procedure cost of flexible bronchoscopic intubation could vary significantly depending on parameters such as annual procedural volumes, the number of available bronchoscopes and video equipment, repair rates, and depreciation periods.

Conclusion

In conclusion, our study demonstrated that flexible bronchoscopic intubation procedures were not adequately compensated at the subject hospital. This may cause several problems. Undervaluing the procedure may deter healthcare providers from purchasing the optimal number of bronchoscopes to save costs and disincentivize them from performing the procedures. Therefore, it is highly recommended that HIRA review their calculations for determining the practice expense RVU component of the procedure. The per-procedure cost, on the other hand, would vary by procedural volume and site of practice which indicates that a further multicenter study is required to confirm the study's findings.

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