Research Article
Volume 6:5, 2021

Pharmacoeconomics: Open Access

ISSN: 2472-1042 Open Access

Cost Comparison of Reusable and Single-Use Bronchoscopes in a Scottish Intensive Care Unit

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Abstract

Background: Bronchoscopy procedures are conventionally associated with complex supporting processes, large capital investments and inevitable repairs. Cost-comparison analysis with the single-use bronchoscope Ambu® aScope™4 Broncho within a UK intensive care unit have never been done before.

Materials and Methods: We conducted a cost-comparison analysis of reusable vs single-use bronchoscopes within the intensive care unit of the Royal Infirmary of Edinburgh via a micro-costing method.

Results: At the current split between reusable and single-use bronchoscopes, the incremental cost of using single-use vs. reusable bronchoscopes was £111. In a binary setup with either reusable or single-use bronchoscopes, the incremental procedure cost was£90. Single-use bronchoscopes were cost-minimising up to 75 annual procedures per reusable bronchoscope. When including a 0.72% and 2.8% risk of cross-infection the incremental cost of was £159 and £352.

Conclusion: Single-use is cost-effective compared with reusable bronchoscopes within the ICU setting.

Keywords: Eco-climatic zone • Fecal sample • Helminth parasites • Prevalence • Ruminant

Introduction

Conventionally, bronchoscopy procedures require complex supporting processes, including tracking, reprocessing, cleaning verification, high-efficiency particulate air (HEPA) storage, and preparation for procedures, and recleaning, to ensure available and clean reusable bronchoscopes (RBs) [1]. Recent evidence has suggested that RBs are often not sufficiently cleaned by high-level disinfection (HLD) to prevent cross-infections, and quality assurance for these procedures is necessary for optimization [2].

The availability of a single-use bronchoscope (SB) (Ambu® aScope™4 Broncho) performing on par with RBs in common ICU procedures has enabled conversion from RBs to SBs. This underlines the importance of a complete understanding and comparison of the costs and clinical outcomes associated with the technologies [3].

McCahon and Whynes published a UK cost-comparison study of RBs vs. SBs in a binary setup in operating theatres and an emergency department [4]. This study found the incremental cost of RBs vs. SBs to be £129. A breakeven point was presented at about 200 procedures – 14 procedures per RB. Similarly, Russell and Ockert proved that SB are cost-minimizing in the operating theatres [2]. Mouritsen et al. assessed the cost-effectiveness of SBs vs RBs in a high throughput perioperative setting and found that SBs were cost-effective as SBs were cost-minimising while diminishing the risk of cross-infection [4]. No UK evidence has been published comparing RBs to SBs in an intensive care unit (ICU) setting.

Our current cost-comparison study elucidates the complexity and costs associated with the supporting processes of RB procedures compared with SB in an ICU setting. Four scenarios are presented: the current base-case split between SB and RB, conversion from the current split to a binary SB or RB setup, and establishment of a new bronchoscope fleet with SB or with RB. The costs associated with the risk of cross-infections are included in the latter scenario [5].

Materials and Methods

We conducted a cost-comparison study of SBs vs. RBs with the primary outcome of monetary incremental costs of RBs vs SBs per bronchoscopy procedure in an ICU. The analysis considers costs or savings for the healthcare provider.

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Received: 29 July, 2021; **Accepted:** 12 August, 2021; **Published:** 19 August, 2021.

Setting

Cost and utilisation data related to flexible bronchoscopy were collected from the Royal Infirmary of Edinburgh ICU and endoscope reprocessing unit. The Critical Care Unit (including the ICU and High Dependency Unit) has 29 beds and had 2710 admissions in 2018[19]. All bronchoscopy procedures performed on the Critical Care Unit could be performed using either an SB or an RB.

Supporting processes

The following processes were included in the analysis. RBs were stored by endoscopy cleaning personnel (ECP) in the ICU HEPA cabinet. When an RB was ordered, it was prepared for the procedure by a clinical support worker (CSW). This included cleaning and lining a transport box, removing the bronchoscope from storage and manually tracking it. Once the bronchoscopy procedure was complete, a physician pre-cleaned the RB, followed by preparation for transport by a CSW. The RB was collected by the ECP and transported to the endoscopy reprocessing unit (ERU). Here, the RB was initially leak tested. A failed leak test required administrative work before sending the RB for repair. Otherwise, following the leak test, the RB was manually cleaned, rinsed, loaded into the automated endoscope reprocessor (AER), unloaded from the AER after HLD, prepared for transport to the ICU, transported to the ICU, and stored. RBs were tracked, enabling a maximum inter-reprocessing time interval of 72 hrs[2]. Weekly cleaning verifications were conducted via protein tests for all AERs and one reusable endoscope per AER.

Data collection

Data collection and micro-costing were conducted from May 2018 to November 2018. RB procedures per year were based on manual tracking records from 2015 to 2017. Numbers of endoscopes reprocessed per year were based on AER washing cycles from 2014 to 2018.The personnel hands-on time were timed by the authors while following RB through reprocessing. Personnel time used for reprocessing included simulated preparation of the RB for a procedure, simulated pre-cleaning after the procedure, simulated preparation for transport, transport to the ERU, leak testing, manual cleaning, rinsing, AER loading, AER unloading, preparation, and transport of the RB to storage in the ICU HEPA cabinet. Consumables were quantified during timing of the individual steps. Costs of consumables were obtained via a central purchasing system. Utility costs for the AER and HEPA cabinets were based on manufacturer instructions for use, and Sørensen and Grüttner for water and electricity, respectively [5]. Preparation time of SBs for procedures was not included in the analysis, since sterile SBs and their monitors were always available from the airway trollies on the ICU.

Capital and utility costs were collected via the Royal Infirmary of Edinburgh finance department.

Data analysis

- Cost data associated with RBs are presented in four main parts:
- Capital and service costs for the ICU;
- Capital and service costs used during reprocessing RBs;
- Consumables and utility costs; and
- Personnel costs.

The cost-model used a short time horizon (one year) and presents the cost per procedure.

Cost data for SBs comprise capital costs for a monitor and consumable costs for SBs.

To account for time preference, a discount rate of 3.5% was used over the depreciation period in accordance with the expected lifespan of the equipment [2]. All costs were projected to 2018 prices [3].

The ICU had two monitors, three RBs and one RB supporting rack system, two Olympus BF-260 Evis Bronchoscopes, one Olympus BF-XP260F Evis Hybrid Bronchoscope, and an Olympus Evis Lucera Elite Video System with a fixed service agreement including repair costs. In our cost model, the service cost is equally allocated between the three RBs and rack system. Annual procedures were based on the mean annual procedures from 2015 to 2017.

Personnel costs were estimated based on a yearly working time of 2,038 hrs/year for registrar doctors, 1,838 hrs/year for consultants, and 1,591 hrs/year for ECP and CSWs [4]. The personnel costs were £1.18/min for physicians and £0.39/min for ECP and CSWs. Personnel costs for pre-cleaning were distributed equally between consultants and registrar doctors. A 6% constant was added to the costs of ECP and CSWs to account for personnel turnover. Additionally, leak-testing, loading and unloading of AER, transport and storage costs were multiplied by a constant (C) to account for the maximum 72-hr inter-reprocessing interval.

C=8760 hours/72 hours/RB procedures per year/#RBs

The reprocessing unit had five AERs, three leak testing devices, three endoscope flushing systems, and three detergent dispenser systems. To estimate the cost per reprocessing, a distribution key based on total endoscopes reprocessed per year, were used. Additionally, AER and leak testing equipment costs were multiplied by C.

All data analysis was conducted within a commercially available spreadsheet. Three scenarios were model mentioned below.

Scenario a – current split: For scenario a, the current split between RB and SB procedures per year were utilised to estimate the capital cost per RB and SB procedure. To estimate the robustness of the base-case one-way deterministic sensitivity analyses were carried out. In the sensitivity analysis we varied the cost input and procedure volume parameters by ± 50% and illustrated the results in a tornado chart.

Scenarios b and c – conversion form current split: Procedure costs and annual saving or expense were reported for conversion from the current split to 100% SBs (scenario b) or RBs (scenario c).

Scenario d – new binary setup: Scenario d compares the procedure cost and annual costs of establishing a new binary bronchoscopy setup with either RBs or SBs. A one-way sensitivity analysis was used to test the robustness against varying annual procedures. The procedure cost for SBs and RBs from the sensitivity analysis was further illustrated graphically. The risks and derivative costs of cross-infection were tested in scenario d. 0.72% and 2.8% risk of cross-infection was based on Terjesen et al. and Mouritsen et al., respectively. A derivative cost of an infection of £9350 was used [5,7].

Results

A total average of 139 annual bronchoscopy procedures is conducted in the ICU, comprising 115 procedures with RBs and 24 with SBs.

Scenario a – current split

The mean personnel time utilized to prepare a ready-to-use RB was 83.6 min at a cost of £41(Table 1).

Task	Time per RB (mean±SD)	Personnel
Preparation RB and rack system (simulation)	15 min (n=1)	CSW
Pre-cleaning (simulation)	8.4 min (n=1)	Physician
Preparation for transport (simulation)	6 min (n=1)	CSW
Transport to Endo Unit	5.22 min (n=1)	ECP
Cleaning dirty side	18.90 min ± 5.01 (n=7)	ECP
Handling clean side	29.49 min ± 0.43 (n=2)	ECP
Cleaning verification	0.14 min	ECP
Failed leak test	0.42 min	ECP
Total time per procedure	83.58 min	
Annual time	160.20 hrs	

Table 1. Scenario a – current split.

Table describes each supporting process and the time spends per process to ensure one ready to use reusable bronchoscope (RB). Further the personnel's conducting each process is listed including: Clinical support worker (CSW), endoscopy cleaning personnel (ECP) and physician.

Each supporting process was associated with usage of single-use equipment and utilities at a combined cost of £21. For the 115 RB procedures performed, capital and service costs covered by the ERU amounted to £42 per procedure (Table 2).

	Capital cost	Service cost	Depreciation period
Bronchoscopes			
2 x Olympus BF-260 Evis Bronchoscope	£26,363	£2388	10 years
Olympus BF-XP260F Evis Hybrid Bronchoscope	£31,635	£2388	10 years
Rack cystem			
Olympus Evis Lucera Elite Video System	£64,174	£2388	10 years
2 x Ambu® aView™	£1,792	NA	5 years
Miscellaneous			
12 x Nurse tag	£100	NA	10 years
3 x Scope tag	£250	NA	10 years
Cleanascope trolley incl. 6 trays	£906	NA	7 years
6 x Cleanascope lids	£620	NA	7 years
AER			
5 x Cantel Medical Medivators Rapid AER	£30,054	£1864	10 years
HEPA cabinet			
HEPA cabinet	£8,963	£892	10 years
Leak testing equipment			
3 x Olympus MU-1	£1,187	NA	7 years
Endoscope flushing system			
3 x FlushTech GI	£1,039	NA	7 years
Detergent dispenser system			
3 x EcoLab	£475	NA	7 years
Metal tray for AER			
5 x Metal tray	£243	NA	7 years
Reprocessing room			
Establishing room	£2,109,030	NA	30 years
Average cost of 64m2	£167,624	NA	30 years
Total capital investment related to RB	£2,595,612		
Total capital investment related to SB	£3,583		

Table 2. Description of capital investments incl. capital cost, service costs and depreciation period.

The capital and service costs covered by the ICU were £158 and £83, respectively. The three RBs had been repaired 13 times in their lifetime, amounting to a repair to procedure ratio of 1/44, covered by the service contract. The RB procedure cost was £344. The cost of conducting a SB procedure included capital investment of £1792 for a monitor and £199 for an SB, resulting in a procedure cost of £233. Using these figures, the single-use technology was £111 cheaper per procedure (Figure 1).

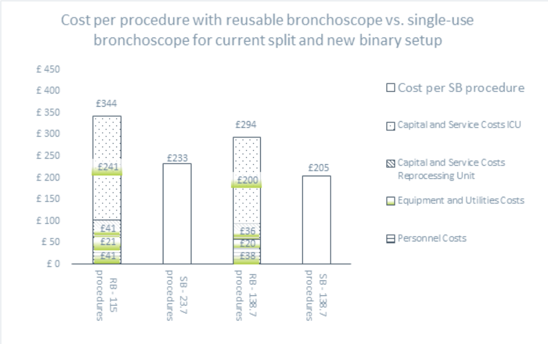

Figure 1. Cost per bronchoscopy procedure with a reusable bronchoscope (RB) or single-use bronchoscope (SB), both scenario a and d results are presented.

The one-way sensitivity analyses overall verified the robustness of the base-case result. However, the base-case result was most sensitive to variations in annual procedures per RB (Figure 2).

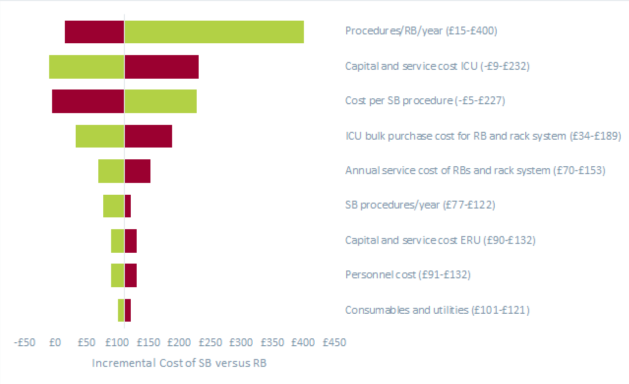

Figure 2. Tornado chart multiple one-way (univariante) sensitivity analysis of cost and procedure volume parameters varied ± 50%.

The incremental cost of single-use bronchoscopes (SB) and reusable bronchoscopes (RB) midpoint is £111 and is equal to the base-case result from the cost-comparison analysis of scenario A –current split. Higher values (red) for capital and service costs ICU, ICU bulk purchase cost for RB and rack systems, annual service costs of RBs and rack system, SB procedures/year, capital and service costs ERU, personnel cost, consumables increased the incremental saving of SB, whereas lower values (green) reduced the saving of SB. Higher values (red) for procedures/RB/year and cost per SB procedure decreased the saving of SB, whereas lower values (green) increased the saving of SB. A breakeven point occurred at 62 annual procedures per RB.

Scenario b and c – conversion from current split

In scenario b, a complete conversion from the current split to SBs, the ICU saved £120 per procedure or £16,700 annually. In scenario c, a complete conversion to RB from the current split, resulted in a saving per procedure of £31 and annual savings of £4,258. Hence, the incremental cost of converting from the current split to RB vs. SB was £90 per procedure or £12,441 annually.

Scenario d – new binary setup

Establishing a new bronchoscope fleet utilising only RBs resulted in a procedure cost of £294 and annual costs of £40,830. Alternatively, conducting all procedures with SB resulted in a procedure cost of £205 or annual costs of £28,388. Therefore, the incremental cost for RB vs. SB was £90 per procedure or £12,441 annually. See the cost distribution in figure 1. The one-way sensitivity analysis showed a shift of dominance from SB to RB dependent on the number of annual procedures. The breakeven point occurred at 75 procedures per RB, (Figure 3).

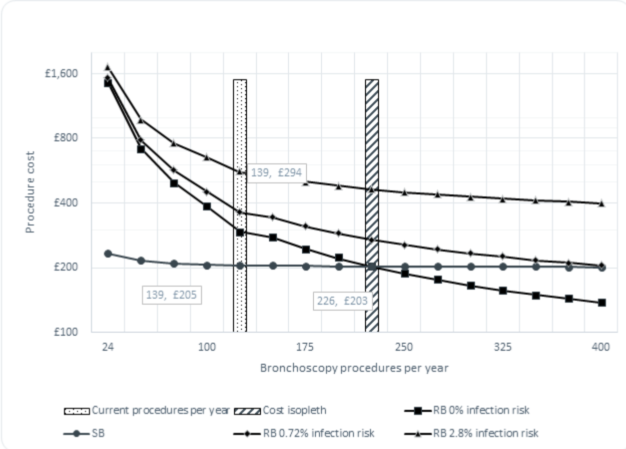

Figure 3. Procedure cost for single-use bronchoscope (SB) and reusable bronchoscope (RB) dependent on number of bronchoscopy procedures per year and 0.72% and 2.8% risk of cross-infection.

Risks of cross-infection of 0.72%, and 2.8% resulted in additional costs per RB procedure of £67, £262, respectively, that is, a RB procedure cost of £362 and £556. Thus, the incremental costs for RBs vs SBs per procedure were £159 and £352; resulting in an annual saving of £21,740 and £48,744, see figure 3.

Discussion

RB procedure, subsequent reprocessing and costs constitute a major hidden expense in hospital budgets [1]. A new single-use technology has proven to perform on par with RBs within the ICU; thus, evidence is required of all costs associated with each technology to enable evidence-based decisions [3]. Currently, three UK cost-comparison studies have compared RBs and SBs [2]. No UK studies have investigated the incremental cost of utilizing RBs vs. SBs within an ICU setting, nor what the actual cost is per procedure in a split fleet between SBs and RBs. As there are up to 100 complex interdisciplinary supporting processes, oversight can easily be lost while estimating direct costs of use [1]. Furthermore, the potential for bronchoscope-vectored cross-infections entails a derivative hidden cost that is pivotal to include in the decision-making process [5].

We conducted micro-costing of RBs and SBs. This enabled a cost-comparison of the four scenarios: a. the current split between RBs and SBs, b. and c. conversion from the current split to 100% SBs or RBs and d. establishing a new bronchoscopy setup with 100% RBs or SBs. By a full switch from the current split to 100% use of SBs, The Royal Infirmary of Edinburgh could achieve an annual saving of

£16,670 in direct cost of use. The annual incremental cost of converting to SBs vs RBs was £12,441.

The 83.58 min hands-on time and expenditure of single-use consumables and utilities is in accordance with the findings of of stead et al. [1]. The other available UK cost-comparison studies noted lower hands-on-time of 41 min and 50 min per RB procedure [2,7].

Capital investment and service agreements are significant cost drivers for RBs, according to the sensitivity analyses. This is consistent with the other UK cost-comparison studies [2,7]. The Royal Infirmary of Edinburgh ICU conducts a range of procedures, including percutaneous dilatory tracheostomies (PDT). PDT has been found to increase the procedure-to-repair ratio from 1/61 across all procedures to 1/27 for PDT alone. The incremental cost per RB PDT procedure compared with SB is £141 [7]. An increased repair rate can potentially result in delayed procedures due to no available RBs. In the current setup, bronchoscope availability is ensured by utilizing SBs. Further, to increase the likelihood of having an available RB for off-time periods, the reprocessing interval is shorter than the 72 hrs currently included in the cost model. To the knowledge of the authors, this is the only cost-comparison study accounting for maximum bronchoscope hang time [8].

In scenario d – a new binary setup, the direct cost-of-use of SB and RB was compared, showed that breakeven occurs at 75 procedures/bronchoscope/year. This means our unit would need to perform extra 37 procedures per device for RBs to become cost equivalent to SBs. Find breakeven points at 22.5 and 14.3 procedures/bronchoscope/year, respectively. In these studies, breakeven occurres at a lower procedure frequency than in our study. When the risks of cross-infection and derivative costs were included, the breakeven point between SB and RB occured at a higher procedure frequency. There is a large uncertainty associated to the risk of cross-infection due to the low level of evidence. However, the presence of outbreak literature underpins that there is a risk of bronchoscope vectored cross-infection.

Conclusion

The current study did not consider disposal costs or the environmental impact of the SB. However, Sørensen and Grüttner find that the environmental impact of reprocessing RBs is equal to or greater than that of SBs. The extent of single-use consumables and utilities listed in underpins the significant environmental impact of reprocessing RBs. Our cost-comparison study is the first to assess the economic consequences of converting from RB to SB within an UK ICU. The results demonstrate that SB is cost minimizing while diminishing the risk of cross-infection compared with RB in all scenarios.

Acknowledgements

We would like to thank all the personnel in Royal Infirmary of Edinburgh for helping us micro-cost all the supporting processes associated to bronchoscopy procedures, especially Charge Nurse Steve Walls from Ward 118, ICU and the finance department.

Authors' contributions

Mark Dunn developed the initial idea for the study. All authors contributed to the final design of the study. Mark Dunn mapped out the processes needed to be included in the cost model. Mark Dunn and Rasmus Russell contributed equally to the data collection. Rasmus Russell conducted the computations, which were validated by Mark Dunn. The authors have contributed equally to the writing the manuscript.

Declaration of conflict of interest

R.V. Russell is employed by Ambu A/S as Corporate Health Economist.

M.J.G. Dunn is on an Ambu A/S sponsored board of key opinion leaders.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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How to cite this article: Russell, Rasmus Vinther, and Dunn MJG. "Cost Comparison of Reusable and Single-Use Bronchoscopes in a Scottish Intensive Care Unit." *Pharmacoeconomics*6 (2021) : 16901