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Original Research Article

A Comparison of Soda Lime (Intersurgical) with Amsorb® plus: The Cost Implications

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Abstract

This was a prospective study comparing the cost implications between two carbon dioxide (CO_2) absorbers, soda lime (Intersurgical) and AMSORB® PLUS. The study was conducted over two 4-week periods in two dedicated operating theatres using Datex Ohmeda Aestiva/5 anaesthetic machines. AMSORB® PLUS was used during the first four weeks and soda lime (Intersurgical) the following four weeks. General anaesthesia was administered as routinely done but fresh gas flow (FGF) during the maintenance phase was limited to a maximum flow of 2 L/min. The CO_2 absorber was only changed when there was evidence of exhaustion. Total duration of anaesthesia, sevoflurane (bottles) and CO_2 absorber (kg) consumption, and amount of waste product (kg) was calculated at the end of each study period. The total cost of delivering general anaesthesia was lower in the AMSORB® PLUS group, RM82.40 (USD19.89)/hour versus the soda lime group, RM91.50 (USD 22.09)/hour (p=0.17), which translates to a 10% reduction in cost per hour. Reduction in sevoflurane consumption in the AMSORB® PLUS compared to the soda lime group was also not statistically significant (p=0.22). The only significant finding was the reduction in CO_2 absorber consumption in the AMSORB® PLUS group as compared to soda lime group (p=0.001). In conclusion, AMSORB® PLUS consumption was significantly reduced compared to that of soda lime. However, the use of AMSORB® PLUS did not significantly reduce sevoflurane consumption nor the total cost of delivering general anaesthesia. Given the superior safety profile, AMSORB® PLUS may be a suitable, cost-effective alternative to soda lime in the daily practice of anaesthesia.

Keywords: $CO_{2,}$ cost, general anaesthesia, sevoflurane, soda lime

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Introduction

General anaesthesia is commonly provided by delivering oxygen and anaesthetic gases (volatile anaesthetics) via the circle breathing system. The presence of a carbon dioxide (CO_2) absorber allows for rebreathing of anaesthetic gases. This conserves anaesthetic gases, consequently decreasing cost and environmental pollution, whilst avoiding the hazards of CO_2 rebreathing.

Soda lime is a commonly used CO_2 absorber in the circle breathing system. It consists of alkalis comprising 94% calcium hydroxide ($Ca(OH)_2$), 5% sodium hydroxide (NaOH) and less than 0.1% potassium hydroxide (KOH),with a moisture content of 15-19%. Silica (0.2%) prevents disintegration of the granules into powder and the addition of a dye changes the colour of the granules when soda lime is exhausted. One Kg of soda lime can absorb more than 120 litres of CO_2 (1). CO_2 is primarily removed by $Ca(OH)_2$, but NaOH and KOH assist in this process (2).

However, desiccated soda lime is known to produce toxic compounds when it interacts with volatile anaesthetic agents (3). The degradation of sevoflurane produces formaldehyde (HCOH) and compound A. The latter has been reported to be nephrotoxic in rats. On the other hand, desflurane, enflurane and isoflurane produce carbon monoxide (CO) when degraded by desiccated or partially desiccated soda lime. Serious CO poisoning with neurological injury has been reported with desflurane anaesthesia. KOH may be the primary determinant in the production of CO (3). In addition to the potential production of these toxic compounds, degradation of volatile anaesthetics increases anaesthetic costs (3).

New generations of CO_2 absorbers have been developed to overcome these problems. AMSORB®PLUS is a strong alkali free (NaOH and KOH) CO_2 absorber. The primary reaction is between CO_2 and $Ca(OH)_2$ forming calcium carbonate ($CaCO_3$) and water. Calcium chloride ($CaCl_2$) and calcium sulphate ($CaSO_4$) prolong the life of $Ca(OH)_2$ and increase its speed of absorption by maintaining granule strength and optimising hydration respectively. A colour indicator changes from white to violet when $Ca(OH)_2$ is exhausted or desiccated. Studies have shown that CO_2 absorption is not compromised in the absence of NaOH and KOH (2,4,5).

In addition, AMSORB® PLUS unlike other CO2 absorbers, does not degrade volatile agents. The formation of toxic compounds (particularly compound A and CO) is thus negligible or non-existent (6-12). Non-degradation of volatile anaesthetic agents resulting in no formation of toxic compounds may ensure patient safety while reducinganaesthetic consumption and cost. Another cost advantage of AMSORB® PLUS lies in the way it is disposed, where soda lime is disposed in healthcare waste while AMSORB® PLUS in domestic waste (3). The cost involved in managing domestic waste is lower than that of healthcare waste.

However, AMSORB® PLUS is slightly more expensive per unit weight as compared to soda lime. To date,there has only been one study looking at the cost implications of replacing soda lime with AMSORB® PLUS in clinical practice (3). The study showed an overall reduction of 28% in the cost of delivering general anaesthesia using AMSORB® PLUS. The amount of AMSORB® PLUS used, and thus the amount of waste product was significantly lower compared to soda lime. Our study was modified from the prior study,with standardised methodology for the two groups (AMSORB® PLUS and soda lime) with respect to the duration of anaesthesia, usage of both study compounds (time of CO_2 absorber granule replacement) and fresh gas flow (FGF), in the intent to compare the cost implications of soda lime versus AMSORB® PLUS in clinical practice.

This study was carried out to compare the cost implications of soda lime versus AMSORB® PLUS in clinical practice, in terms of volatile anaesthetic and CO_2 absorber consumption and CO_2 absorber disposal.

Materials and Methods

This was a prospective study conducted after obtaining institutional ethics committee approval which was conducted over two 4-week periods. AMSORB® PLUS was used during the first 4-week period followed by soda lime (Intersurgical) during the second 4-week period. The study was conducted in two dedicated elective operating theatres using the Datex Ohmeda Aestiva/5 anaesthetic machines with the circle breathing system. Loose granules (as opposed to prefilled canisters) of soda lime and AMSORB® PLUS were used.

Only sevoflurane was used during the study, therefore the desflurane vapouriser was removed from the back bar. The vapourisers were maximally filled up at commencement of the study. Subsequent refills were done by the anaesthetic doctor in charge of that theatre. A new bottle of volatile anaesthetic agent (Sevoflurane, Baxter, 250 ml) was used for the first refill and subsequent new bottles were used when the previous one was finished. At the end of the study period, the vapourisers were maximally filled-up again to determine the total amount of volatile anaesthetic (based on number of bottles) that had been consumed. The empty bottles were placed in a specified box in the respective operating theatres and collected at the end of each day by an assigned anaesthetic technician.

Newly replaced CO_2 absorbers were used at commencement of the study and only replaced when it was exhausted (uniform colour change visible through the canister or when inspired CO_2 was detected on the monitor). Replacement of the granules was done by the assigned anaesthetic technician and each replacement was documented.

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General anaesthesia was delivered by multiple operators. Standard monitoring (non invasive blood pressure, pulse oximetry, lead II electrocardiography and capnography) was observed in all patients. The patients were pre-oxygenated (100% O_2 at 8 L/min) to achieve an end tidal O_2 of more than 85%. All patients were induced intravenously, while inhalational induction (sevoflurane 8% at fresh gas flows of 8 L/min till the patient lost consciousness) was performed where indicated. The mode of induction of anaesthesia was documented in the data collection form. Anaesthesia was maintained with sevoflurane, targeting a minimum alveolar concentration (MAC) of 1-1.3 in an oxygen / air mixture. The maximum fresh gas flow (FGF) allowed throughout the maintenance phase was 2 L/min. FGF during the maintenance phase and the total duration of anaesthesia (time from pre-oxygenation till FGF was discontinued) was documented.

At the end of the study period, the amount of CO_2 absorber (weight) and volatile anaesthetic (number of bottles) used was documented. Subsequently, the total cost of volatile anaesthetic and CO_2 absorber consumption, in addition to waste disposal cost was determined.

Statistical analysis was performed using the T-test to compare the mean cost, sevoflurane consumption, and CO_2 absorber consumption between the two groups. A p value of < 0.05 was considered statistically significant.

Results

General anaesthesia was administered to seventy-four patients during the study period. There was no significant demographic difference between the two groups as shown in Table 1.

For the AMSORB® PLUS group, the total duration of anaesthesia was 74.1 hours and mean duration of anaesthesia was 1.8 ± 0.8 hours. Inhalational induction was performed in six (14.6%) patients, and the mean FGF during the maintenance phase was 1.6 ± 0.4L/min. On the other hand, the total duration of anaesthesia was 63.5 hours and mean duration of anaesthesia was 1.9 ± 1.0 hours for the soda lime group. Five (15.2%) of the patients were induced by inhalational technique and the mean FGF during the maintenance phase was 1.5 ± 0.5 L/min. There was no significant difference in terms of mean duration of anaesthesia and FGF between the two groups ($p > 0.05$).

The total cost calculated based on sevoflurane and CO_2 absorber consumption, and disposal of waste product is shown in Table 2.

For the AMSORB® PLUS group, the total cost for delivering general anaesthesia was RM 6104.80 (RM 82.40/hour) and for the soda lime group the total cost was RM 5817.60 (RM 91.50/hour). Cost per patient was calculated based on cost per hour multiplied by the duration of anaesthesia for each patient. The mean cost per patient was RM 149.89 ± 64 and RM 176.30 ± 97 for the AMSORB® PLUS and soda lime groups respectively, which was not significantly different ($p = 0.17$).

Total sevoflurane consumption was 17 bottles (4250 ml, 57 ml/hour) in the AMSORB® PLUS group and16 bottles (4000 ml, 62 ml/hour) in the soda lime group.

Table 1: Demographic data. Values are expressed as mean ± SD or number (%) where appropriate.

	AMSORB® PLUS (n = 41)	**Soda lime (n = 33)**
Paediatric, Age (yrs)	6 (14.6), 6.5 ± 3.5	5 (15.2), 6.0 ± 3.0
Adult, Age (yrs)	35(85,4), 45 ± 19	28 (84.8), 47 ± 17
BMI (kg/m^2)	25.3 ± 3.9	24.9 ± 3.8
Gender		
Male	25 (60.9)	20 (60.6)
Female	16 (39.1)	13 (39.4)

Table 2: Cost comparison between AMSORB® PLUS and soda lime

	AMSORB® PLUS			**Soda lime**		
	Amount	**Cost (RM)**	**Total cost (RM)**	**Amount**	**Cost (RM)**	**Total cost (RM)**
CO_2 absorber consumption	11 kg	32 per kg	352	16 kg	20 per kg	320
CO_2 absorber waste product disposal	11 kg	Negligible	Negligible	16 kg	5.20 per kg	83.20
Sevoflurane consumption	17 bottles	338.40 per bottle	5752.80	16 bottles	338.40 per bottle	5414.40
Total cost (RM)			6104.80			5817.60

Sevoflurane consumption per patient was calculated based on sevoflurane consumption/hour multiplied by duration of anaesthesia for each patient. The mean sevoflurane consumption per patient was 103.7 ml ± 44.4 and 119.5 ml ± 66 for the AMSORB® PLUS and soda lime groups respectively, which was not significantly different ($p = 0.2$). As for CO_2 absorber consumption, total consumption was 11 kg (148.6 g/hour) for AMSORB® PLUS and 16 kg (251.6 g/hour) for soda lime. CO_2 absorber consumption per patient was calculated based on CO_2 absorber consumption/hour multiplied by duration of anaesthesia for each patient. Thus, the mean CO_2 absorber consumption per patient was 269.2 ± 115 g and 483.6 ± 267g for the AMSORB® PLUS and soda lime groups respectively, which was significantly different ($p = 0.001$).

Discussion

The cost of healthcare systems is increasing worldwide. The current economic climate has put pressures on healthcare systems and providers, anaesthesiologists included, to minimise cost without compromising patient safety. Anaesthetic drugs typically comprise approximately 5% of a hospital pharmacy budget (13). Although the cost of anaesthesia constitutes only a small proportion of the total healthcare cost, anaesthetic drug expenditure has been an important focus as part of this cost-containment effort (14). In the analysis of perioperative costs, depending on the type of surgery, anaesthesia accounted for about 10-15% of the total cost of hospital stay. Inhalational agents accounted for 5% of the total budget and 20% of all drug costs of an anaesthesia department (15). Employing cost saving measures when delivering inhalational agents could considerably reduce the anaesthetic department expenditure given its major contribution to the total drug cost.

To date, only few studies have emphasised the need to improve alertness amongst practitioners with regards the cost of anaesthetic drugs, fluids and disposables, so as to optimise resources (16-18). When considering general anaesthesia, total intravenous anaesthesia is more costly than inhalational anaesthesia (19,20). Inhalational anaesthesia using low fresh gas flows has been proven to reduce volatile anaesthetic consumption thus is more cost effective (14,21,22, 23). However, low flow anaesthesia is not without problems, with the potential for CO formation which is inversely related to the flow rate (24,25). Ahmed et al. found a 28% reduction in the overall cost of delivering general anaesthesia using AMSORB® PLUS as compared to soda lime (3). However, the reduction in the amount of sevoflurane used in the AMSORB® PLUS group was not statistically significant ($p = 0.22$). Nevertheless, the amount of AMSORB® PLUS used, thus the amount of waste product, was significantly lower compared to soda lime ($p = 0.006$).

Our results were consistent with the above findings. The cost was lower, though not statistically significant in the AMSORB® PLUS group compared to the soda lime group (RM82.40/hour versus RM91.50/hour, $p = 0.17$) which translates to a 10% reduction in cost per hour. The reduction in sevoflurane consumption in the AMSORB® PLUS group compared to the soda lime group was also not statistically significant ($p = 0.22$). The only significant finding in our study was the reduction in CO_2 absorber used in the AMSORB® PLUS group compared to the soda lime group ($p = 0.001$). This may be contributed by the fact that AMSORB®PLUS has superior CO_2 absorption capacity (5). Bed packing of its granules is optimised with its range of granule size, permitting inter granular spaces between the larger granules to be filled in by smaller granules. This leads to reduced channeling of anaesthetic gas, which results in better CO_2 absorption (4).

This study had its limitations. Firstly, fresh gas flow rate, a major determinant of volatile anaesthetic consumption was standardised during the maintenance phase of anaesthesia where the maximum FGF allowed was 2 L/min. However, the FGF may have been manipulated to flows exceeding 2 L/min intra-operatively to tailor to the patient's requirement as and when necessary. This was further compounded by the involvement of multiple operators with inter-personnel variability in anaesthetic management. Additionally, although inhalational induction was standardised at 8 L/min, subsequent reduction and duration of gas flows above 2 L/min was not documented. Any modification in anaesthetic technique was not accounted for in the results as the changes were presumed to be transient. Secondly, sevoflurane consumption was based on the number of bottles used where the bottle was only disposed once the content was finished. However, the content of the last bottle may have not been completely emptied but was nevertheless still considered as one used bottle (regarded as 250 ml of sevoflurane consumption). Besides that, the sevoflurane bottle (Baxter) used is an open system bottle whereby the bottle cover has to be taken off and replaced with an adapter which fits into the vapouriser. No consideration was made for the lost vapour when the bottle was opened, and for any spillage of the liquid when filling the vapouriser. This would have overestimated the actual sevoflurane consumption. Thirdly, CO_2 absorber was changed based on colour change visible to the anaesthetic technician through the canister. Assessment of granule colour change in this manner did not take into consideration the actual colour of the granules in the core of the canister. This may have lead to unnecessary change of the granules and thus the cost incurred. Besides that, the violet colour of exhausted AMSORB®PLUS is not reversible because it does not contain strong alkali (4). However, the colour change of partially exhausted soda lime is reversible. When it is allowed to stand for a few hours, it appears to 'regenerate' as the surface carbonate is diluted by hydroxide ions migrating from within the granule (26). This may have lead to less frequent change of soda lime. Lastly, the cost of disposing AMSORB® PLUS was negligible but there was no actual calculation made to sum up the actual cost incurred. Thus the total cost of general anaesthesia using AMSORB® PLUS was concluded on the assumption that no cost was involved in disposing AMSORB® PLUS.

Conclusion

AMSORB® PLUS consumption was significantly reduced compared to soda lime. However, the use of AMSORB® PLUS did not significantly reduce sevoflurane consumption nor the total cost of delivering general anaesthesia. Given its superior safety profile, AMSORB® PLUS may be a suitable, cost-effective alternative to soda lime in the daily practice of anaesthesia.

Conflict of Interest

The authors stated that there are no conflicts of interest to declare.

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