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Nebulizer versus metered dose inhaler with space chamber (MDI spacer) for acute asthma and chronic obstructive pulmonary disease exacerbation: attitudes of patients and healthcare providers in the COVID-19 era

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ABSTRACT

Objective: Short-acting bronchodilators for asthma and chronic obstructive pulmonary disease (COPD) exacerbations are commonly delivered by nebulizers although administration using metered dose inhaler with space chamber (MDI spacer) has been shown to be equally efficacious. There are few studies examining patients' and healthcare providers' attitudes on the two administration methods in adults. This study explores patients' and healthcare providers' attitudes on the use of nebulizer versus MDI spacer for acute asthma and COPD exacerbations in adults.

Methods: Patients admitted for asthma or COPD exacerbations, doctors, and nurses in a university-affiliated hospital were surveyed from 1 April 2021 to 30 September 2021 regarding their views on the effectiveness, ease of use, preparation and administration, side effects, and infection risk of the two administration methods.

Results: Ninety-nine patients, 103 doctors, and 650 nurses completed the survey. 60.6% of patients perceived nebulizer to be more effective. Patients who found nebulizer more comfortable were more likely to prefer nebulizer (OR 43.97, $p=0.01$), while those who associated it with a greater infection risk were less likely to prefer nebulizer (OR 0.15, $p=0.03$). 49.5% of doctors and 49.1% of nurses perceived nebulizer to be more effective, compared to 10.7% and 34.5%, respectively, for MDI spacer. Effectiveness and patient comfort influenced doctors' and nurses' preference for nebulizer while ease of preparation and administration influenced nurses' preference only.

Conclusions: Patients and healthcare providers perceived nebulizer to be more effective. Factors unique to each group influenced their preference for nebulizer.

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Introduction

Inhaled short-acting bronchodilators (SAB) for the treatment of acute asthma and chronic obstructive pulmonary disease (COPD) exacerbations are widely administered via nebulizer at the emergency department (ED) and inpatient setting. The alternative administration route of metered dose inhaler (MDI) with space chamber (MDI spacer) may have comparable efficacy. For example, delivery of SAB via MDI spacer is equally efficacious in preventing hospitalizations as well as improving lung function in both children and adults with asthma exacerbations (1). The

use of MDI spacer in children may even be superior, with studies reporting shorter duration of stay in ED and fewer side effects (2). There is less data regarding the use of MDI spacer in COPD exacerbations, but evidence to date does not conclusively support the use of one modality over another (3).

Proponents for MDI spacer cite advantages such as lower costs, better side effect profile in children, and affording patients and caregivers the opportunity to learn MDI spacer use (4–6). With the ongoing COVID-19 pandemic, there are also concerns about spreading airborne or droplet infections through

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aerosol-generation with nebulizer therapy (7). Despite differing views on the infectious risks posed by nebulizers (8), several societies and guidelines, such as the Global Initiative for Asthma, recommend avoiding nebulizer use (9). Accordingly, healthcare institutions, including those in Singapore, have pivoted away from using nebulizer for acute asthma and COPD exacerbations since the start of the COVID-19 pandemic.

Changes to ingrained healthcare practices, such as replacing nebulizer with MDI spacer, can be met with resistance from patients and healthcare providers alike. Although previous studies examined stakeholders' concerns regarding the switch to MDI spacer (10,11), majority of such studies were conducted in pediatric populations and focused predominantly on healthcare provider's attitudes (12,13). Perceptions of the two modalities consequent to the COVID-19 pandemic also remain unstudied.

This study aims to examine the perceptions of patients, doctors, and nurses on the use of MDI spacer versus nebulizer for treating adult patients with acute asthma or COPD exacerbations. Study results may help inform on measures necessary to improve acceptance of MDI spacer use in adults.

Methods

This was a cross-sectional study conducted in Changi General Hospital, a 1000-bed university-affiliated, public hospital in Singapore. Surveys were administered to participants from 1 April 2021 to 30 September 2021. This study was submitted to the Singhealth Centralised Institutional Review Board (reference number 2021/2037) and exempted from further ethics review.

Prior to the COVID-19 pandemic, SAB were, by default, delivered via nebulizer in a typical dosing regimen of salbutamol 5 mg with ipratropium bromide 250 mcg as frequently as clinically indicated in our institution. Since February 2020, our institution switched to using MDI spacer as default in the ED and inpatient wards, with a typical dosing regimen of 10 puffs of salbutamol 100 mcg with 6 puffs of ipratropium bromide 20 mcg, although nebulizers may still be used for patients with life-threatening bronchospasm or if they have poor response to MDI spacer. Nurses prepare and administer SAB to patients regardless of administration route. Respiratory therapists in our hospital are not involved in SAB administration. There were no nation-wide or hospital-wide publicity following the COVID-19 pandemic about possible infection risks associated with certain respiratory care procedures.

Study population and survey administration

Our respiratory nurses review about 95% of patients admitted for asthma and COPD exacerbations for inhaler technique assessment and self-care management; they are not involved in the day-to-day administration of medications. During the study period (except weekends and public holidays), hospitalized patients with asthma or COPD exacerbation who were referred to our respiratory nurses were screened for eligibility. Only patients who had previous experience with both MDI spacer and nebulizer during an acute exacerbation were eligible to participate; those without mental capacity to consent or complete the survey were excluded. Patient surveys were administered face-to-face by respiratory nurses but all patient responses were anonymized.

Doctors from clinical departments that manage acute medical patients either in the ED or inpatient wards, and nurses from the ED, inpatient wards, and outpatient clinics were invited by email and/or text message to complete an anonymous online survey. Only those who had ever prescribed or administered SAB via both MDI spacer and nebulizer were eligible to participate. Email and text reminders were sent regularly during the study period.

Development of survey questions

As there were no questionnaires available to specifically assess patients' perception and satisfaction of inhaled treatment delivered during an acute exacerbation, we developed questions for the patient survey based on previously identified domains for patient satisfaction of inhaled devices (14) that were felt to be relevant in the acute setting: effectiveness, ease of use, and side effects, including the risk of spreading airborne infections.

Surveys for healthcare provider were developed by identifying main themes reported in literature concerning the use of MDI spacer in the acute setting (11,15). The common themes included effectiveness, ease of preparation, ease of administration, and side effects.

Based on the aforementioned domains, survey items were generated and refined. Content validation was performed by inviting patients, doctors, and nurses to review their respective surveys. Five patients, nine respiratory specialists, and nine senior registered nurses with average nursing experience of 13 years were asked to rate the relevance of each survey item to its content domain from a scale of 1 to 4 (1 being not relevant; 4 being highly relevant). Only survey

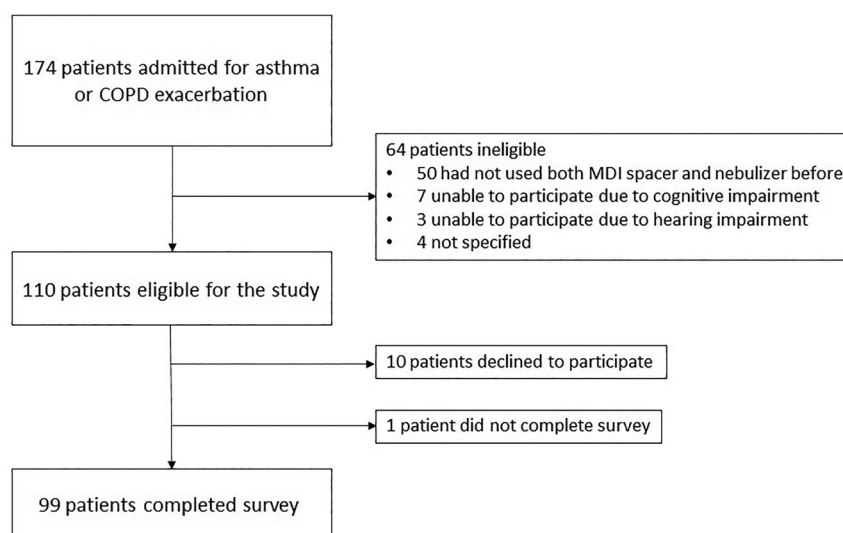


Figure 1. Consort diagram showing patients who were recruited and completed the study. MDI=metered dose inhaler.

items with scale-level content validity indices (S-CVI) greater than 0.8 were included in the final survey (16). Content experts also provided suggestions on the wording and phrasing of survey questions. A sample of the survey questions can be found in [Supplementary Appendix 1](#).

Statistical analysis

Data were analyzed using SPSS version 26 (IBM, Armonk, NY). Continuous variables were expressed as mean (standard deviation) and categorical variables were expressed as number (percentage). Comparisons of categorical variables between groups were performed using chi-square tests. Logistic regression models were fitted to identify independent factors associated with the perception that nebulizer was more effective, as well as the preference for nebulizer. p values <0.05 was taken to be statistically significant.

Results

Patients' results

During the study period, 174 patients with asthma or COPD exacerbations were seen by our respiratory nurses. Of these, 64 patients were ineligible, 10 patients were eligible but declined participation, and one did not complete the survey. Ninety-nine patients completed the survey and contributed data for analysis ([Figure 1](#)).

The majority of patients were male (68%) with mean age 61 years. Most patients (81%) were successfully treated with MDI spacer alone, with only 11%

requiring both MDI spacer and nebulizer in hospital. Other baseline characteristics are detailed in [Table 1](#).

As shown in [Figure 2](#), most patients felt that nebulizer was more effective, easier to use, and more comfortable than MDI spacer. Majority felt that side effect profile for both modalities was similar although nebulizer had a higher infection risk. Despite 60% of patients reporting greater perceived effectiveness of nebulizer, only 49.5% expressed a preference for nebulizer for future exacerbations. For patients who expressed their preference for nebulizer in the future, the majority chose it for its perceived effectiveness (67.3%), faster relief of breathlessness (67.3%), and ease of use (65.3%). Those who preferred MDI spacer in the future selected it mainly for its ease of use (52.5%) and lower infection risk (52.5%) ([Figure 3](#)).

As shown in [Figure 2](#), 29.3% and 62.6% of patients found MDI spacer and nebulizer, respectively, easier

Table 1. Baseline characteristics of patients ($n=99$).

Age, mean $\pm$ SD (years)	61 $\pm$ 16
Female, n (%)	32 (32.3)
Ethnicity, n (%)	
Chinese	29 (29.3)
Malay	51 (51.5)
Indian	14 (14.1)
Others	5 (5.1)
Admission diagnosis, n (%)	
Asthma	60 (60.6)
COPD	39 (39.4)
Salbutamol MDI use at home prior to admission, n (%)	
Yes	88 (88.9)
No	11 (11.1)
Bronchodilator modality received during current admission, n (%)	
MDI only	81 (81.8)
Nebulizer only	7 (7.1)
MDI and nebulizer	11 (11.1)

COPD = chronic obstructive pulmonary disease; MDI = metered dose inhaler; SD = standard deviation.

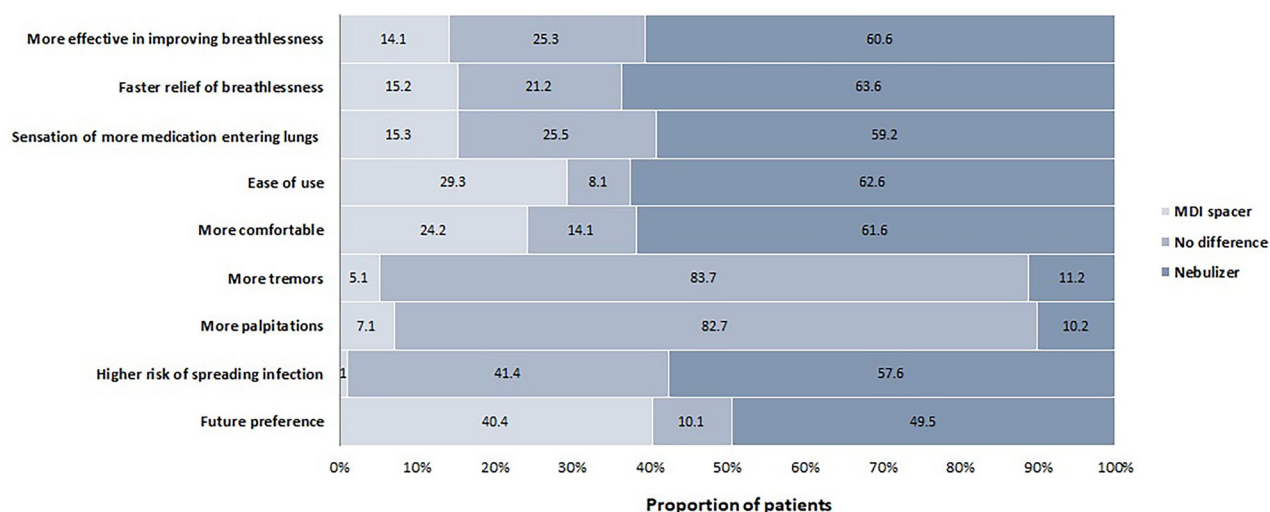


Figure 2. Patients' perceptions on effectiveness, ease of use, side effects, and preference for MDI spacer vs. nebulizer. MDI=metered dose inhaler.

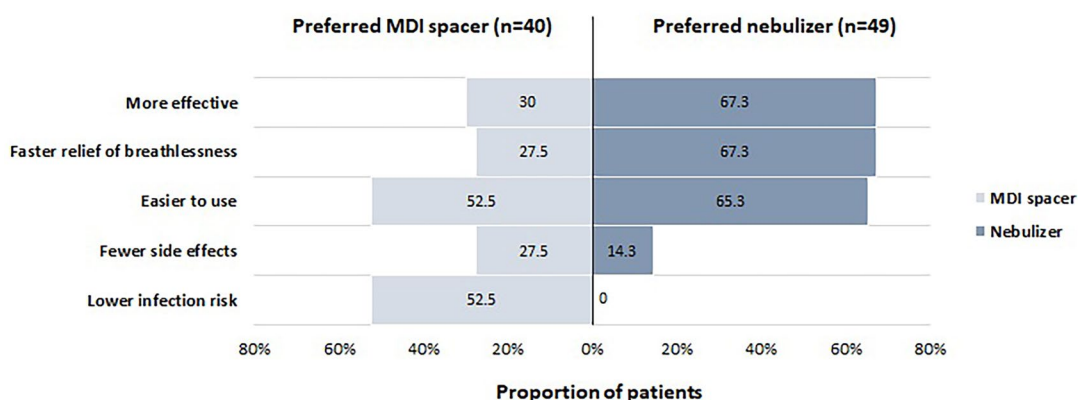


Figure 3. Patient reasons for preferring MDI spacer or nebulizer. MDI=metered dose inhaler.

to use. Patients favored MDI spacer in this respect because less time (58.6%) and coordination (24.1%) were required, and fewer steps were involved (17.2%). In contrast, patients felt nebulizer was easier to use mainly because less coordination was required (87.1%), fewer steps were involved (54.8%), and less time was needed (33.9%).

Patients who found nebulizer more effective or easier to use were not significantly different from the other patients in their baseline characteristics (Supplementary Appendix 2). Notably, receipt of both MDI spacer and nebulizer during admission did not influence their preference for nebulizer. However, patients were more likely to prefer nebulizer if they found its use to be more comfortable (OR 43.97, 95% CI 2.65–728.88; $p=0.01$) while those who associated it with a greater infection risk were less likely to prefer it (OR 0.15, 95% CI 0.03–0.8; $p=0.03$) (Supplementary Appendix 2).

Doctors' results

Survey invitations were emailed to 370 doctors from the departments of emergency medicine, respiratory medicine, internal medicine, and other specialties. One hundred and three responded, but data were not available for the number who did not participate due to ineligibility. Most respondents were consultant-level specialists, with the majority from internal medicine (29.1%), followed by respiratory medicine (26.2%) and emergency medicine (25.2%) (Table 2).

Doctors' perceptions are shown in Figure 4 and a break-down of responses according to their respective specialties can be found in Supplementary Appendix 3. Doctors from respiratory medicine (OR 0.22, 95% CI 0.06–0.83, $p=0.03$), emergency department (OR 0.22, 95% CI 0.06–0.82, $p=0.02$), and internal medicine (OR 0.19, 95% CI 0.05–0.74, $p=0.02$) were less likely to find nebulizer more effective compared to doctors from other departments (Supplementary

Table 2. Baseline characteristics of doctors ($n=103$).

Age, mean $\pm$ SD (years)	36 $\pm$ 8
Female, n (%)	51 (49.5)
Work experience, n (%)	
0–5 years	32 (31.1)
6–10 years	20 (19.4)
11–15 years	23 (22.3)
16–20 years	15 (14.6)
>20 years	13 (12.6)
Job seniority, n (%)	
Junior level	
House officer	3 (2.9)
Medical officer/Junior resident	33 (32)
Middle level	
Resident physician	10 (9.7)
Registrar/Senior resident	13 (12.6)
Senior level	
Associate consultant*	1 (1)
Consultant*	24 (23.3)
Senior consultant*	19 (18.4)
Clinical department	
Internal Medicine	30 (29.1)
Respiratory Medicine	27 (26.2)
Emergency Department	26 (25.2)
Other departments	
Cardiology	5 (4.9)
Endocrine	5 (4.9)
Gastroenterology	3 (2.9)
Geriatrics medicine	3 (2.9)
Rheumatology	1 (1)
Unspecified	3 (2.9)

*A consultant physician is one who has completed postgraduate specialty training.

Appendix 4). Tables 3 and 4 list the reasons why doctors perceived MDI spacer or nebulizer to be easier to prepare and administer.

More doctors preferred prescribing nebulizer (47.6%), compared to 33% who preferred MDI spacer, and 19.4% with no preference. Despite their preference

for nebulizer, 56.3% of doctors agreed that MDI spacer should remain the default modality even after the pandemic.

Perceiving nebulizer to be more effective and more comfortable for patients was independently associated with doctors' preference for nebulizer (Supplementary Appendix 4).

Nurses' results

Survey invitations were sent to 1442 registered nurses working in the inpatient wards, ED, and clinics. Six hundred and fifty nurses responded to the survey. The majority of respondents were working in the inpatient wards (82.5%) and most had been working in the nursing profession for ≤ 10 years (61.5%). Other baseline characteristics are detailed in Table 5.

Briefly, 49.1% and 34.5% of nurses perceived nebulizer and MDI spacer, respectively, to be more effective, while 16.5% felt there was no difference. Compared to nurses with the least number of work experience (0–5 years), only those who worked 6–10 years were more likely to find nebulizer therapy more effective (OR 1.73, 95% CI 1.15–2.6, $p=0.01$). Nurses working in the ED were also more likely than those working in the inpatient wards to find nebulizer more effective (OR 3.36, 95% CI 1.29–8.76, $p=0.01$) (Supplementary Appendix 5).

More than half the nurses felt that preparation of MDI spacer was easier (51.1%). A numerically greater proportion of nurses felt that nebulizer (44.9%)

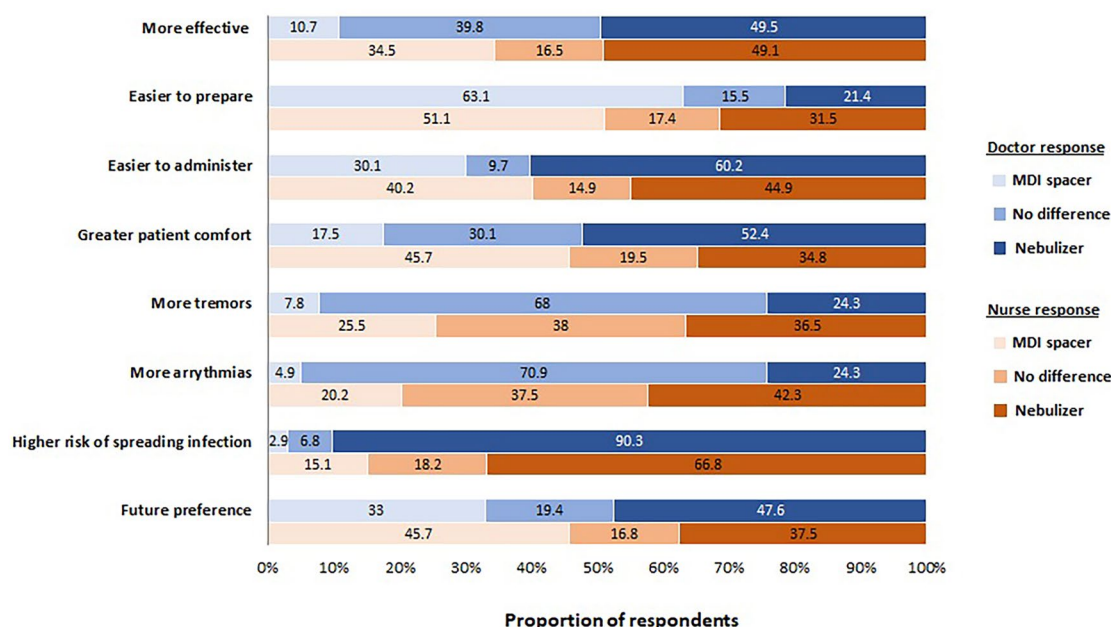


Figure 4. Perceptions of doctors and nurses on the effectiveness, ease of preparation, ease of administration, side effects, and preference for MDI spacer vs. nebulizer. MDI=metered dose inhaler.

Table 3. Reasons why doctors perceived MDI spacer or nebulizer to be easier to prepare.

Specialty	MDI spacer					Nebulizer				
	All (n=65)	ED (n=10)	RM (n=21)	IM (n=18)	Others (n=16)	All (n=22)	ED (n=12)	RM (n=4)	IM (n=5)	Others (n=1)
Equipment is more accessible	44 (67.7)	6 (60)	14 (66.7)	11 (61.1)	13 (81.3)	5 (22.7)	5 (41.7)	0	0	0
Fewer equipment required	50 (76.9)	8 (80)	18 (85.7)	10 (55.6)	14 (87.5)	4 (18.2)	3 (25)	1 (25)	0	0
Fewer steps involved	57 (87.7)	8 (80)	19 (90.5)	15 (83.3)	15 (93.8)	15 (68.2)	9 (75)	4 (100)	2 (40)	0
Others	1 (1.5)	1 (10)	0	0	0	3 (13.6)	1 (8.3)	0	2 (40)	0

Values in brackets indicate percentage of respondents for each specialty.

ED = emergency department; IM = internal medicine; MDI = metered dose inhaler; RM = respiratory medicine.

Table 4. Reasons why doctors perceived MDI spacer or nebulizer to be easier to administer.

Specialty	MDI spacer					Nebulizer				
	All (n=31)	ED (n=4)	RM (n=7)	IM (n=11)	Others (n=9)	All (n=62)	ED (n=22)	RM (n=17)	IM (n=15)	Others (n=8)
Equipment is more accessible	21 (67.7)	3 (75)	5 (71.4)	6 (54.5)	7 (77.8)	24 (38.7)	8 (36.4)	6 (35.3)	5 (33.3)	5 (62.5)
Fewer equipment required	23 (74.2)	4 (100)	7 (100)	4 (36.4)	8 (88.9)	27 (43.5)	7 (31.8)	10 (58.8)	5 (33.3)	5 (62.5)
Fewer steps involved	24 (77.4)	3 (75)	6 (85.7)	6 (54.5)	9 (100)	43 (69.4)	14 (63.6)	14 (82.4)	10 (66.7)	5 (62.5)
Others	0	0	0	0	0	4 (6.5)	2 (9.1)	0	2 (13.3)	0

Values in brackets indicate percentage of respondents for each specialty.

ED, emergency department; IM, internal medicine; MDI, metered dose inhaler; RM, respiratory medicine.

Table 5. Baseline characteristics of nurse (n=650).

Age, mean $\pm$ SD (years)	34 $\pm$ 9
Female, n (%)	611 (94)
Work experience, n (%)	
0–5 years	195 (30)
6–10 years	205 (31.5)
11–15 years	129 (19.8)
16–20 years	54 (8.3)
>20 years	67 (10.3)
Area of work, n (%)	
Inpatient ward	536 (82.5)
Outpatient clinic	62 (9.5)
Emergency department	23 (3.5)
Missing data	29 (4.5)

COPD, chronic obstructive pulmonary disease; MDI, metered dose inhaler; SD, standard deviation.

compared to MDI spacer (40.2%) was easier to administer, although this was not statistically significant ($p=0.187$). Other responses are shown in Figure 4. Reasons provided by nurses for ease of preparation and administration of MDI spacer or nebulizer are listed in Tables 6 and 7.

More nurses preferred using MDI spacer compared to nebulizer in the acute setting (45.7% vs. 37.5%) whereas 16.8% had no preference. Nurses who perceived that nebulizer was more effective, easier to prepare, easier to administer, and more comfortable for patients were more likely to prefer nebulizer (Supplementary Appendix 4).

Table 6. Reasons why nurses perceived MDI spacer or nebulizer to be easier to prepare.

Area of work	MDI spacer					Nebulizer				
	All (n=332)	ED (n=7)	Inpatient (n=273)	Clinic (n=34)	Others (n=18)	All (n=205)	ED (n=10)	Inpatient (n=167)	Clinic (n=19)	Others (n=9)
Equipment is more accessible	252 (75.9)	4 (57.1)	212 (77.7)	23 (67.6)	13 (72.2)	121 (59)	5 (50)	99 (59.3)	12 (63.2)	5 (55.6)
Fewer equipment required	215 (64.8)	3 (42.9)	178 (65.2)	22 (64.7)	12 (66.7)	73 (35.6)	4 (40)	61 (36.5)	6 (31.6)	2 (22.2)
Fewer steps involved	245 (73.8)	6 (85.7)	199 (72.9)	25 (73.5)	15 (83.3)	160 (78)	9 (90)	131 (78.4)	13 (68.4)	7 (77.8)
Others	9 (2.7)	0	7 (2.6)	2 (5.9)	0	10 (4.9)	2 (20)	7 (4.2)	1 (5.3)	0

Values in brackets indicate percentage of respondents for each area of work.

ED = emergency department; MDI = metered dose inhaler.

Table 7. Reasons why nurses perceived MDI spacer or nebulizer to be easier to administer.

Area of work	MDI spacer					Nebulizer				
	All (n=261)	ED (n=5)	Inpatient (n=211)	Clinic (n=28)	Others (n=17)	All (n=292)	ED (n=15)	Inpatient (n=243)	Clinic (n=25)	Others (n=9)
Equipment is more accessible	178 (68.2)	2 (40)	147 (69.7)	19 (67.9)	10 (58.8)	232 (79.5)	12 (80)	205 (84.4)	10 (40)	5 (55.6)
Fewer equipment required	198 (75.9)	5 (100)	160 (75.8)	21 (75)	12 (70.6)	198 (67.8)	11 (73.3)	163 (67.1)	19 (76)	5 (55.6)
Fewer steps involved	112 (42.9)	0	102 (48.3)	7 (25)	3 (17.6)	203 (69.5)	9 (60)	170 (70)	18 (72)	6 (66.7)
Others	4 (1.5)	0	3 (1.4)	1 (3.6)	0	3 (1)	1 (6.7)	1 (0.4)	1 (4)	0

Values in brackets indicate percentage of respondents for each area of work.

ED, emergency department; MDI=metered dose inhaler.

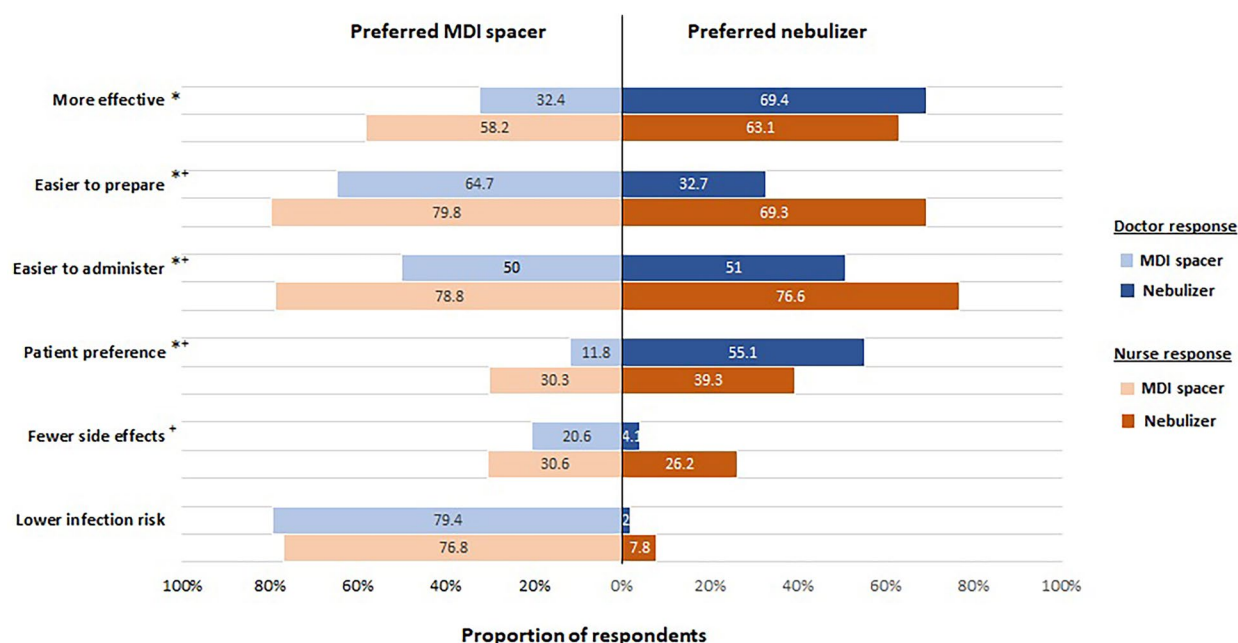


Figure 5. Healthcare provider reasons for preferring MDI spacer or nebulizer (* $p < 0.05$ between doctors and nurses who preferred MDI spacer; + $p < 0.05$ between doctors and nurses who preferred nebulizer). MDI=metered dose inhaler

As shown in Figure 5, reasons for preferring MDI spacer or nebulizer therapy differed between doctors and nurses.

Discussion

There has been much hesitancy in adopting MDI spacer for acute asthma and COPD exacerbations; 70% of doctors in pediatric emergency departments had never prescribed SAB via MDI spacer for acute asthma exacerbations (10). This is despite established MDI spacer efficacy in most patients with asthma and COPD (1,3) and deficiencies associated with the prescription and administration of nebulizer (17). The COVID-19 pandemic provided an impetus for the switch to MDI spacer but for this practice to be sustainable, support from patients and healthcare providers is needed (11). Perceptions and preferences gathered from this study may help identify barriers to MDI spacer use that are relevant to each stakeholder.

Our study revealed that most patients perceived nebulizer to be more effective than MDI spacer. The reasons were unclear although a placebo effect, with nebulizer being a more complicated and noisier apparatus, cannot be discounted. A systematic review reported a statistically non-significant trend favoring nebulizer to MDI spacer for improving lung function post treatment in patients with COPD (3), raising the possibility that patients with COPD exacerbations might find nebulizer more effective. Patients who had

used (and failed) salbutamol MDI therapy at home might also be expected to find nebulizer more effective. However, both assumptions were not supported by our data. Our observation contrasted with Khoo et al. where majority of patients found MDI spacer more effective instead (15). Methodological differences may account for this disparity as the study by Khoo et al. comprised of a smaller patient cohort who were interviewed immediately after receiving MDI spacer.

Most patients in our study found nebulizer easier to use mainly because less coordination was required. This highlights an important difference between adult and pediatric populations. Caregivers of pediatric patients find MDI spacer easier to use because children are often unable to hold still with a nebulizer mask, and may not tolerate the accompanying noise or mist well (11,18).

Despite a more favorable perception of the effectiveness and ease of use of nebulizer over MDI spacer, fewer than half the patients expressed a future preference for nebulizer. It is found that those who associated it with a greater infection risk were less inclined to prefer it, suggesting that healthcare choices may have been affected by the pandemic. Concerns about infection risks was also one of the main reasons why healthcare providers preferred MDI spacer. Awareness about infection risks has been reported since the severe acute respiratory syndrome (SARS) outbreak (10) but likely heightened during the COVID-19 pandemic (19).

Of the three participant groups, a comparatively greater proportion of doctors felt there was no difference in effectiveness between nebulizer and MDI spacer, but almost half still thought that nebulizer was more effective. Perceiving nebulizer to be more effective independently predicted doctors' and nurses' preference for nebulizer. Doctors in departments other than ED, respiratory medicine, and internal medicine may find nebulizer more effective due to unfamiliarity with up-to-date evidence. Interestingly, in contrast to ED doctors, ED nurses were more likely to find nebulizer more effective. Although sicker patients presenting to the ED may respond to MDI spacer more poorly since patients with life-threatening exacerbations were generally excluded from previous efficacy studies, discordance with doctors' responses counters this argument. Rather, ED nurses may be less familiar with the evidence for MDI spacer (10). Knowledge barriers can be overcome with education interventions (6), and would be an important area to address.

More than half the doctors who preferred nebulizer did so because of perceived patient preference. Although patient preference has been shown to be one of the main domains influencing medical decisions (20), our results demonstrated that this was more a perceived rather than an actual barrier (10) – more than half the surveyed patients actually either preferred MDI spacer or had no preference.

Ease of preparation and administration significantly influenced nurses' preference for nebulizer. Nurses interviewed in a previous qualitative study reported greater demands on nursing time with MDI spacer as they had to teach and supervise MDI spacer use, a constraint not imposed by nebulizer therapy (12). This was similar to what was observed in our study with nurses favoring nebulizer as less time was spent at the bedside.

In the study by Khoo et al. which was conducted during the SARS outbreak, majority of nurses preferred nebulizer and felt that nebulizer should be the default modality after the outbreak (15). In our study, more nurses preferred MDI spacer and would want it to remain the default modality even after the pandemic. It is unclear how soon after the SARS outbreak the study by Khoo et al. was conducted, but our study was conducted 14 months after the onset of COVID-19 pandemic in Singapore, during which nurses might have become more accustomed to using MDI spacer, and hence the greater acceptance of this modality.

Ours is one of the few studies that examined perceptions and preferences of healthcare providers and patients on the use of MDI spacer and nebulizer in the adult population. To our knowledge, it is also

the only study of this nature conducted after the onset of the COVID-19 pandemic. The study design allowed responses from the three participant groups to be compared, enabling potential barriers to MDI spacer use unique to each group to be identified easily.

Despite these merits, our study has some limitations. First, response rate to the surveys for healthcare providers was <50% despite regular reminders although this is typical of electronic surveys conducted on medical professionals (21,22). Second, our results may not be generalizable to other populations because MDI spacer is administered only by nurses in our institution whereas other institutions may allow respiratory therapists or patients to administer MDI spacer (23). Third, we did not examine cost-effectiveness and its impact on participant preferences. However, cost-effectiveness is highly dependent on a health system's setup, e.g. person responsible for administering MDI spacer or nebulizer, whether reusable or disposable spacers are used, and the cost of spacers (23). In Singapore, patients in public healthcare institutions co-pay their medical bills, with varying amounts of government subsidy depending on various eligibility criteria.

Conclusion

Despite established evidence, patients, doctors, and nurses still perceive nebulizer therapy to be more effective than MDI spacer; more needs to be done to educate patients and healthcare providers about the effectiveness of MDI spacer. In addition, improving the ease of MDI spacer administration through measures that shorten time spent at patients' bedside is likely to increase acceptability of MDI spacer among nurses. Concerns about the risk of infection with nebulizer are an important factor driving patients' preference for MDI spacer.

Declaration of interest

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