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Impact of structured curriculum with simulation on bronchoscopy

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Abstract

Background and objective: Simulation enhances a physician's competency in procedural skills by accelerating ascent of the learning curve. Training programmes are moving away from the Halstedian model of 'see one, do one, teach one', also referred as medical apprenticeship. We aimed to determine if a 3-month structured bronchoscopy curriculum that incorporated simulator training could improve bronchoscopy competency among pulmonary medicine trainees.

Methods: We prospectively recruited trainees from hospitals with accredited pulmonary medicine programmes. Trainees from hospitals (A, B and C) were assigned to control group (CG) where they received training by traditional apprenticeship while trainees from hospital D were assigned to intervention group (IG) where they underwent 3-month structured curriculum that incorporated training with the bronchoscopy simulator. Two patient bronchoscopy procedures per trainee were recorded on video and scored independently by two expert bronchoscopists using the modified Bronchoscopy Skills and Tasks Assessment Tool (BSTAT) forms. A 25 multiple choice questions (MCQ) test was administered to all participants at the end of 3 months.

Results: Eighteen trainees participated; 10 in CG and eight in IG with equal female:male ratio. Competency assessed by modified BSTAT and MCQ tests was variable and not driven by volume as IG performed fewer patient bronchoscopies but demonstrated better BSTAT, airway anaesthesia and MCQ scores. Bronchoscopy simulator training was the only factor that correlated with better BSTAT ($r = 0.80$), MCQ ($r = 0.85$) and airway anaesthesia scores ($r = 0.83$), and accelerated the learning curve of IG trainees.

Conclusion: An intensive 3-month structured bronchoscopy curriculum that incorporated simulator training led to improved cognitive and technical skill performance as compared with apprenticeship training.

KEYWORDS
bronchoscopy, competency, education, procedure, simulation-based training

INTRODUCTION

The Halstedian model of 'see one, do one, teach one' paradigm has been the traditional method of acquired learning. Procedural training is based on the apprenticeship model where competency relies on volume. Learning medical procedures depends on the student's ability and the teacher's effectiveness.[1–4] The learner not only needs to know about the indications, contraindications and complications of the procedure, and its risk versus benefit but also one's own ability. Although flexible bronchoscopy is generally safe with less than 1% complication rate of bleeding, hypoxia, respiratory depression, pneumothorax, arrhythmia and cardiorespiratory arrest,[5] its execution still requires technical skills and good hand–eye coordination. Inexperienced bronchoscopists report higher complication rates and lower biopsy yield especially in the first 3 months of training.[6] Moreover, bronchoscopy is performed by physicians in disciplines such as pulmonary medicine, critical care, paediatrics, thoracic surgery, anaesthesia and otolaryngology.

International guidelines state that basic competency is achieved when the trainee has performed 100 bronchoscopy procedures in a supervised setting.[7–9] This minimum number is not evidence based as trainees' confidence and manual dexterity can vary. Bronchoscopy education is unique, as it comprises of cognitive and psychomotor components; however, training programmes are variable with different assessment criteria for competency. Some programmes provide didactic lectures with hands-on supervision whilst others incorporate simulation training with supervisors completing checklists at certain milestones of training. It is conceivable that lack of standardization of training programmes could lead to variable competency and proficiency outcomes.[10]

Our bronchoscopy training in pulmonary and critical care medicine programme is akin to the apprenticeship model that is highly dependent on teacher–student interactions and no simulation practice on high or low fidelity models before actual patient bronchoscopy. This can impose significant burden on patient safety and comfort if the novice physician is unfamiliar with handling of the bronchoscope and instruments, intubation, navigation and airway anatomy. High-fidelity simulation provides computer-generated three-dimensional (3D) images of the airways, a proxy bronchoscope and instruments to procure specimens; tracks performance metrics; and generates scores. It allows the novice physician opportunity for repetitive training in a safe stress-free environment with real-time feedback. Our aim was to determine the impact of an intensive 3-month structured bronchoscopy curriculum that incorporated simulation training on cognitive knowledge and psychomotor skills. We hypothesized that these educational interventions would lead to improved knowledge and skill competency when incorporated at any stage of training.

METHODS

Trainees were recruited from university-affiliated hospitals with accredited pulmonary medicine training programmes. The trainees from hospitals A, B and C were assigned to the control group (CG) where they acquired bronchoscopy skill and knowledge in accordance with their institutional training uniformly ensconced in medical apprenticeship; supervised patient bronchoscopy procedures; self-directed learning with available resources in recommended reading lists that included web-based Essential Bronchoscopist; and no simulation practice. Trainees from hospital D were assigned to the intervention group (IG) where they undertook a structured curriculum designed with the goal of achieving competency in inspection bronchoscopy. They were encouraged to complete the first three modules of Essential Bronchoscopist,[11] were instructed in the step-by-step bronchoscopy exercise and practised inserting the bronchoscope through the nose, larynx and vocal cords into the central, lobar and segmental airways (Appendix S1 in the Supporting Information) to achieve muscle memory. The main thrust of the curriculum was on mastery learning with deliberate practice. IG had to log 1 h of training on the bronchoscopy simulator (Immersion Medical Inc., Gaithersburg, MD) per week for 12 weeks, practise different case scenarios in the modules provided by the simulator as well as discuss procedural consults using the four-box approach inspired by Albert Jonsen's work on clinical ethics and promoted by Henri Colt. These interventions occurred concurrently as supervised patient bronchoscopy procedures (see Text Box 1).

SUMMARY AT A GLANCE

Bronchoscopy represents a skill with cognitive and psychomotor aspects that can cause variability in competency irrespective of seniority and number of procedures performed. Our study identifies three caveats with impact on bronchoscopy competency, namely structured curriculum, simulation training and assessment tools which can be adopted in any procedural training programme.

TEXT BOX 1 Bronchoscopy curriculum

Reading list: modules 1–3 of Essential Bronchoscopist

Bronchoscopy step-by-step exercise (Appendix S1)

Bronchoscopy simulator:

Practice 1 h/week with bronchoscopy step-by-step exercise and case scenarios

Supervised patient bronchoscopy procedures

Four-box approach for procedural consult

Initial evaluation	Procedural strategies
• Examination and functional status • Significant comorbidities • Support system • Patient preferences and expectations	• Indications, contraindications and results • Team experience • Risk–benefits analysis and therapeutic alternatives • Informed consent
Techniques and results	**Long-term management**
• Anaesthesia and peri-operative care • Techniques and instrumentation • Anatomic dangers and other risks • Results and procedure-related complications	• Outcome assessment • Follow-up tests and procedures • Referrals • Quality improvement

Assessment:

Two patient bronchoscopy videos at 6 and 12 weeks for grading using modified Bronchoscopy Skills and Tasks Assessment Tool and airway anaesthesia score forms.

Instruction to perform a systematic examination of the tracheobronchial tree and capture pictures of right upper, middle and lower lobes as well as left upper division, lingula and lower lobe. To return to the trachea before any sampling procedures to calculate the total examination time.

25 Multiple choice questions test at 12 weeks.

The participants' demographic data were collected and each had to perform bronchoscopy under local anaesthesia and conscious sedation on two patients which were anonymously recorded on video at 6 and 12 weeks. These bronchoscopy videos were then graded independently by two blinded experts using modified Bronchoscopy Skills and Tasks Assessment Tool (BSTAT) where posture, hand positions and equipment handling, entry into sub-segments on demand as well as specific tasks were omitted due to the mode of assessment. We added two fields: the first was the number of attempts before successful intubation of the vocal cords, and the second on adequacy of airway anaesthesia that carried a maximum of nine points (Appendix S2 in the Supporting Information). The participants were instructed to perform a systematic examination of the tracheobronchial tree and capture pictures of right upper, middle and lower lobes as well as left upper division, lingula and lower lobe. Once they had completed examination of the airways, they were to return to the trachea before any sampling procedures to calculate the total examination time. A validated test comprising of 25 multiple choice questions (MCQ) was administered at the end of 12 weeks to assess cognition.[12]

Statistical analysis

BSTAT, airway anaesthesia and MCQ test scores determined overall bronchoscopy performance. Differences between the two groups were compared using Mann–Whitney *U*-test for non-parametric variables. Inter-rater reliability and correlation of variables were analysed by kappa and Spearman's rho, respectively. Statistical analysis was performed with SPSS version 24.0 (SPSS Inc., Chicago, IL) and we report median values and interquartile ranges. *p*-Value of ≤0.05 was considered statistically significant.

RESULTS

Eighteen trainees participated in the study: eight in the IG and 10 in the apprenticeship group (CG) with equal female: male ratio. Eighteen patient bronchoscopy videos were graded at 6 weeks and another 18 videos at 12 weeks. The demographic data of the participants were described in Table 1. There were significant differences in the year of training, number of bronchoscopy procedures performed;

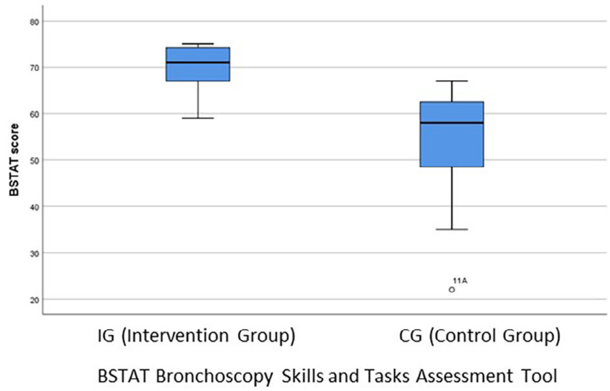

FIGURE 1 Variation in bronchoscopy skill between intervention group and control group

TABLE 1 Demographics and bronchoscopy performance

Demographics	IG (n = 8)	CG (n = 10)	p-Value
Female, n (%)	4 (50%)	5 (50%)	
Year of fellowship	1 (1–2.75)	3 (2.6–3.0)	<0.001*
Number of bronchoscopies	57.5 (40.0–70.0)	142.5 (120.0–200.0)	0.003*
Number of simulation hours	13.5 (8.5–20.0)	0	<0.001*
MCQ scores/25	24.5 (22–25)	19 (16–21)	0.004*
Bronchoscopy performance (n = videos)	**IG (n = 16)**	**CG (n = 20)**	**p-Value**
BSTAT score/75	71 (67–74)	58 (48–63)	<0.001*
BSTAT score/75 (6 weeks)	68 (63–71)	53 (35–59)	<0.001*
BSTAT score/75 (12 weeks)	74 (72–75)	62 (56–66)	<0.001*
Airway anaesthesia score/9	8 (7–9)	5 (4–5.5)	<0.001*
Airway anaesthesia score/9 (6 weeks)	7 (6–8)	5 (4–6)	<0.001*
Airway anaesthesia score/9 (12 weeks)	9 (8–9)	5 (4–6)	<0.001*
Airway examination time (s)	398 (335–464)	262 (199–349)	<0.001*
Vocal cord anaesthesia (s)	81 (57–117)	55 (34–68)	0.001*
Intubation attempts	1.5 (1–2.5)	1 (1–2)	0.65

Note: Values are expressed as median (interquartile range).
Abbreviations: BSTAT, Bronchoscopy Skills and Tasks Assessment Tool; CG, control group; IG, intervention group; MCQ, multiple choice question; n, number of videos analysed.
[*] $p < 0.05$ is statistically significant.

airway anaesthesia, BSTAT and MCQ scores; and time taken to complete airway examination. Majority of the participants in CG were in the third year of fellowship and had performed a median of 143 (range: 120–200) bronchoscopy procedures while those in IG were mostly in the first year of fellowship and had performed a median of 58 (range: 40–70) procedures. CG did not receive any training on the bronchoscopy simulator and had significantly lower BSTAT (median: 58 vs. 71), airway anaesthesia (median: 8 vs. 5) and MCQ scores (median: 24.5 vs. 19.0) compared with IG (Figure 1). There was no difference in the number of intubation attempts in both groups but IG spent a longer time in airway examination (398 vs. 262 s) and airway anaesthesia (81 vs. 55 s). The inter-rater reliability kappa values for BSTAT and airway anaesthesia scores were good at 0.85 (95% CI: 0.73–0.97; $p < 0.0001$) and 0.90 (95% CI: 0.80–1.0; $p < 0.0001$), respectively (Table 2). IG spent a median of 13.5 h (range: 8.5–20) on the bronchoscopy simulator, which was the only factor that showed significant correlation with BSTAT ($r = 0.80$, $p < 0.0001$), MCQ ($r = 0.85$, $p < 0.0001$) and airway anaesthesia scores ($r = 0.83$, $p < 0.0001$). Year of fellowship and number of bronchoscopy procedures performed did not affect these scores. The educational intervention that included simulation training accelerated the skill acquisition curve in IG (Figures 2 and 3).

TABLE 2 Kappa values for BSTAT and airway anaesthesia scores between expert graders

	BSTAT score	Airway anaesthesia score
Kappa value	0.853 (95% CI: 0.73–0.97)	0.9 (95% CI: 0.80–1.0)
p-Value*	<0.0001	<0.0001

Abbreviation: BSTAT, Bronchoscopy Skills and Tasks Assessment Tool.
*$p < 0.05$ is statistically significant.

DISCUSSION

Learning procedures by medical apprenticeship assume competency when minimum numbers mandated by credentialing bodies are fulfilled. Programmes adopt different approaches to bronchoscopy training and have variable assessment methods. Some programmes provide didactic lectures and hands-on supervision and some incorporate simulation training while the rest focus on completing checklists. No single method has been shown to yield the best results but the lack of standardized curriculum would suggest variable outcomes.[13]

Our pulmonary medicine programme is modelled after the American College of Graduate Medical Education (ACGME) requirements where the novice learns from the teacher by observation, immerses in direct patient care under supervision, acquires bronchoscopy skill from multiple patient encounters and attains competency upon successful completion of minimum number of procedures.[2]

Competency is central to any medical procedure as it equips the physician with the knowledge and skill to perform the procedure safely with minimum error and complications.[13,14] Learning bronchoscopy is complex as it has cognitive and psychomotor components. Theoretical knowledge guides patient selection, type of procedure and

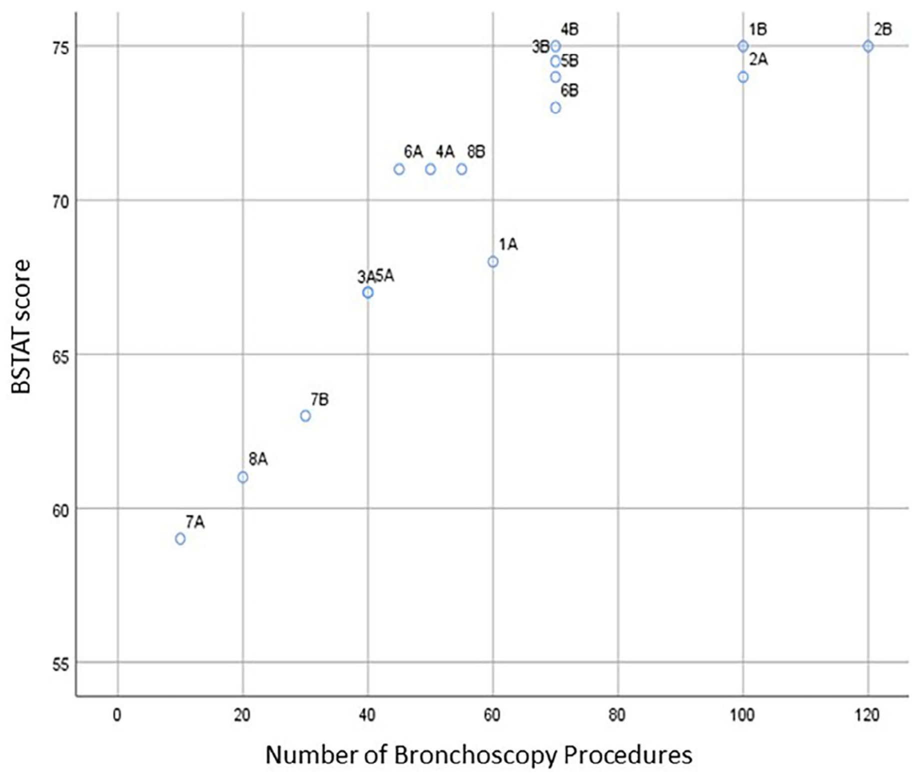

FIGURE 2 Intervention group bronchoscopy performance (participants numbered 1–8, videos coded A at 6 weeks and B at 12 weeks)

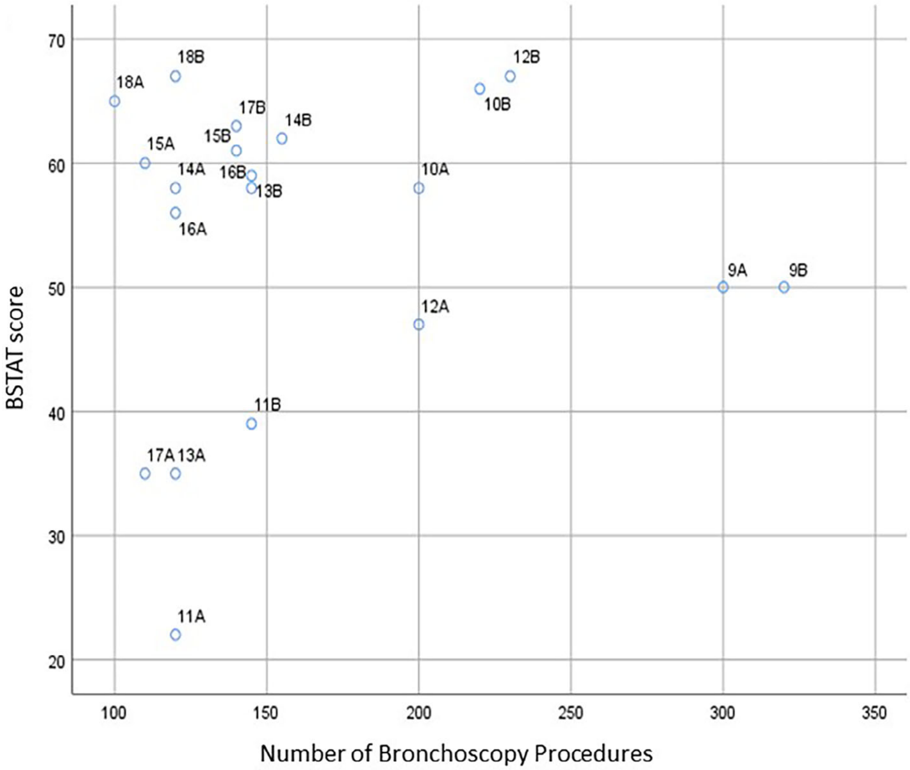

FIGURE 3 Control group bronchoscopy performance (participants numbered 9–18, videos coded A at 6 weeks and B at 12 weeks)

management of complications. Knowledge of the airway anatomy to correctly identify and enter bronchial segments of mucosal abnormalities and pathologies as well as description of respiratory secretions are key aspects of basic bronchoscopy. Psychomotor skill requires training to manoeuvre the bronchoscope within the airways to perform sampling without compromising patient safety and comfort. Our study's objective was to determine if an intensive 3-month structured curriculum comprising of web-based reading of the Essential Bronchoscopist, simulator training 1 h/week with case scenarios and step-by-step bronchoscopy exercise to build muscle memory as well as hands-on supervised patient procedures could lead to rapid attainment of competency. As BSTAT required the assessor to observe the trainee which could risk grader bias as well as stress on the trainee thereby affecting performance, we chose the video format of assessment.[14,15] The bronchoscopy video was subsequently graded by two independent experts using modified BSTAT and airway anaesthesia scoresheets. Both groups took MCQ tests to assess cognition.

Our study revealed marked variation in competency among the trainees that was irrespective of seniority or volume of procedures. CG, mostly in the third year of fellowship, had lower MCQ test, BSTAT and airway anaesthesia scores despite having performed at least 100 supervised patient bronchoscopies at the time of evaluation. An intensive 3-month structured bronchoscopy curriculum with simulator training accelerated the learning curve of IG who were primarily in the first year of fellowship with fewer procedures. Superior BSTAT scores during patient bronchoscopies also proved that procedural skills learned through simulation were transferable to patient care, and our study showed that simulation training introduced at any stage of training aided with skill acquisition.

Our study was limited by the small sample size, but most institutions participated which served as a unique opportunity to assess bronchoscopy skill and knowledge of trainees from different programmes and possibly address deficiencies. Other limitations included modifying BSTAT to omit posture, equipment handling and specific tasks due to video mode of assessment, and airway anaesthesia score based on our standard practice of 'spray as you go technique' with 1-ml aliquots of 1% lidocaine. Topical lidocaine for airway anaesthesia during bronchoscopy is recommended by guidelines.[7–9,16] Studies showed significant reduction in cough and total sedation dose when lidocaine was administered through the bronchoscope but without efficacy difference between 1% and 2% lidocaine preparations.[17,18] In the absence of validation, our modified BSTAT and airway anaesthesia scoresheets still reflected the core skills necessary for bronchoscopy.

Heightened concerns for patient safety have incited a shift from medical apprenticeship to simulation-based approaches that shield patients from the learning phase of procedural training.[19] The apprenticeship model is associated with higher complication rates due to prolonged procedures and larger doses of sedation.[20] A bronchoscopy curriculum must encompass cognitive and psychomotor aspects, and comprise of lectures, books, digital media as well as practice on inanimate models and simulators. A meta-analysis of 17 simulation-based bronchoscopy training trials reported that simulation training led to significant improvements in skills, behaviours and time that were transferable to patient care.[21,22] One report also observed that simulation training increased procedural time but improved quality of bronchoscopy.[23]

Simulation technology includes low-fidelity inanimate airway model and high-fidelity virtual reality (VR) bronchoscopy simulator.[22,24–26] They facilitate training in airway anatomy, muscle memory and hand–eye coordination. The main advantage of the inanimate airway model is the low cost while the disadvantage is lack of interactive capability for situational learning. High-fidelity VR bronchoscopy simulator consists of a proxy flexible bronchoscope and an interface connected to computer (CAE Healthcare, Montreal, Quebec, Canada). Movements of the bronchoscope within 3D images of airways are displayed on the screen with haptic and auditory feedback. The VR simulator tracks performance metrics such as airway collision, number of bronchial segments examined, dose of lidocaine and generates a score at the end of procedure. Instant feedback that the VR simulator provides is essential for effective learning as it validates one's accomplishments and highlights areas for improvement. Thus, the VR bronchoscopy simulator helps the learner acquire skill through repetitive practice and clinical case scenarios in a stress-free environment before proceeding to patients. The main disadvantage is the high cost, which may be prohibitive.

The American and European respiratory societies training guidelines recommend procedural volume as a way to determine competency.[7–9] Our training programme sets 100 flexible bronchoscopies as adequate number for trainees to graduate from fellowship. All trainees in CG had achieved at least 100 bronchoscopies at the time of evaluation but showed marked variation in skill and knowledge that were not volume dependent. Our study supports current evidence that arbitrarily defined numbers are insufficient as markers of effective training because trainees learn at different rates. Moreover, bronchoscopy depends on manual dexterity and hand–eye coordination that can vary according to the individual's ability and using absolute numbers to declare a physician competent in a specific procedure makes little sense.

In conclusion, cognitive and psychomotor aspects of skill training can cause significant variability in procedural competency irrespective of seniority (year of training) and the number of procedures performed. Procedural training should move away from medical apprenticeship and the century-old adage of see one, do one and teach one. Our study identifies three caveats namely structured curriculum, simulation-based training and objective assessment tools with significant impact on cognitive and technical knowledge in bronchoscopy, which can be adopted and implemented in any procedural training programme.

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AUTHOR CONTRIBUTIONS

W. T. Siow: Data curation; investigation; project administration; writing-original draft. **Gan Liang Tan:** Investigation; project administration; writing-original draft. **Chian Min Loo:** Investigation; project administration; writing-original draft. **Kay Leong Khoo:** Investigation; project administration; supervision; writing-original draft. **Adrian Kee:** Investigation; project administration; supervision; writing-original draft. **Augustine Tee:** Investigation; project administration; writing-original draft. **Imran bin Mohamed Noor:** Investigation; project administration; validation; writing-original draft. **Noel Tay:** Investigation; project administration; writing-original draft. **Pyng Lee:** Conceptualization; formal analysis; investigation; methodology; project administration; supervision; validation; writing-original draft; writing-review & editing.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

HUMAN ETHICS APPROVAL DECLARATION

A waiver of consent was granted by the national ethics committee.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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