Validity Evidence for Use of the Ontario Bronchoscopy Assessment Tool in Simulated Settings

BY

DARLENE RUTH NELSON
B.A., North Park University, Chicago, Illinois, 2001
M.D., University of Illinois College of Medicine, Rockford, Illinois 2005

THESIS

Submitted as partial fulfillment of the requirements
for the degree Master of Health Professions Education
in the Graduate College of the
University of Illinois at Chicago, 2020

Chicago, Illinois

Defense Committee:
Rachel Yudkowsky, Chair and Advisor
Yoon Soo Park
John Mullon, Mayo Clinic, Rochester, Minnesota

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abbreviations:

BAL	**Bronchoalveolar lavage**
BSTAT	**Bronchoscopy Skills and Tasks Assessment Tool**
BSET	**Bronchoscopy Step-by-Step Evaluation Tool**
OBAT	**Ontario Bronchoscopy Assessment Tool**
VR	**Virtual reality**

SUMMARY

The purpose of this study was to gather validity evidence for use of the Ontario Bronchoscopy Assessment Tool (OBAT) to assess the technical skills of pulmonary fellows in a high fidelity (cadaver and VR) simulated setting. The Ontario Bronchoscopy Assessment Tool was developed to assess clinical competence of trainees in bronchoscopy. Validity evidence for this tool has been demonstrated in clinical settings. The initial validation study of the OBAT did not assess interrater reliability. There is no validity data for the OBAT in simulated settings.

First-year pulmonary fellows were recruited during a regional bronchoscopy workshop. All participants were assessed by two raters on the technical portion of the OBAT while performing bronchoscopy on a cadaver at three different task stations. Scores from the two raters were compared to determine interrater reliability. A G study was performed to assess sources of variance in the OBAT scores. At the end of the course fellows were asked to perform an additional bronchoscopy on a virtual reality (VR) bronchoscopy simulator. Each of the fellows was assessed by two raters using the OBAT and the BSTAT. Interrater reliability (IRR) was calculated as intraclass correlation (ICC).The relationship between OBAT and BSTAT scores were calculated using Pearson's correlations. Internal consistency of the OBAT was calculated using Cronbach's alpha.

Sixty-nine observations were performed for 42 fellows. The IRR on the technical portion of the OBAT was 0.61, $p<0.001$. The generalizability study demonstrated a G-coefficient of 0.56 across the 3 stations. Variance attributed to the fellows was 11.2%, station was 25.9% and the interaction of fellows with raters nested in stations (fr:s) was 27.6%. The Pearson's correlation between the technical portion of the OBAT and BSTAT scores on the VR simulator across 15 fellows was $r = 0.62$, $p=0.014$.

The technical portion of the OBAT demonstrated good IRR in a high fidelity (cadaver) simulated setting. G-study results suggest the need for repeated observations across different tasks to obtain a stable estimate of skills.

I. INTRODUCTION

Bronchoscopy is a core procedural skill in pulmonary and critical care medicine that requires significant hand-eye coordination. As a skill it has a dominant psychomotor component that requires hand-eye coordination. Traditionally, learning medical procedures such as bronchoscopy rely predominantly on the apprenticeship model of "see one, do one, teach one" and competency inferences are based on the total number of procedures performed. There is no mandated training or performance standard set for competency prior to actual performance on patients. Learning to perform a medical procedure correctly is critical because a certain level of competence is required to ensure patient safety and to effectively reach a diagnosis or outcome.

Competence can be defined as the "habitual and judicious use of knowledge, technical skills and clinical reasoning for the benefit of the individuals and communities." Determination of competence is essential as it drives goals for learning, teaches self-regulation and protects patient's trust. Currently, both training and assessment of bronchoscopy vary substantially across pulmonary and critical care training programs. This diversity of educational process is the consequence of many factors. These include the absence of uniform requirements, structured curricula, and validated measures of competency and proficiency, as well as variability in access to learning materials, patient-based learning experiences and the teaching abilities of physicians designated to be bronchoscopy instructors. This lack of standardization and of defined competency-based metrics means that not all physicians are equally prepared to do the task that they are credentialed for and consequently patients unknowingly bear the burden of procedural-based training.

In the United States, the current recommendation for competency is the successful completion of 100 flexible bronchoscopies during pulmonary fellowship training. This remains

the standard despite the knowledge that there is great variation in the learning curves among novices to obtain the necessary skills.

Inexperienced bronchoscopists have a higher complication rate and a lower yield of positive biopsy results. Current studies using newly developed tools for assessment of performance in bronchoscopy demonstrate that minimal-number recommendations do not well represent what is needed to become proficient. It is therefore imperative that valid assessment tools be used in order to assess competence of trainees before they are allowed to practice independently.

There are several existing bronchoscopy assessment tools. These include the Bronchoscopy Skills and Task Assessment Tool (BSTAT), the Bronchoscopy Step-by-Step Evaluation Tool (BSET), the bronchoscopy assessment tool developed by Konge et al, and the Ontario Bronchoscopy Assessment Tool (OBAT). The BSTAT is a checklist scored on a 100 point scale that assesses the trainee on elements of bronchial anatomy, scope maneuvering, equipment handling and knowledge of mucosal abnormalities. It has been used in virtual simulation, on manikins and during clinical bronchoscopy. The BSET is a tool developed to aid assessment while using standardized training modules to gradually teach bronchoscopy skills. Validity evidence for these tools was developed in a simulated setting, showing good interrater reliability and the ability to differentiate between novices and experts. However, they did not differentiate between clinicians with an intermediate level of bronchoscopy experience and those defined as experts.

Konge et al developed a bronchoscopy assessment tool in order to differentiate between novices, intermediates and experts in bronchoscopy. This tool is a checklist administered by two blinded raters independently viewing video recordings. Evaluation of this tool demonstrated the

ability to reliably differentiate between learner levels, however because the raters were reviewing video of the bronchoscopic image only, they were not able to assess scope handling or provide real time feedback and coaching. Furthermore, Konge's tool does not assess diagnostic sampling, an essential component of bronchoscopy.

Most recently the OBAT was developed with the goal of assessing not only technical aspects of bronchoscopy but also other clinically relevant aspects of the procedure, including pre-procedure assessment, sedation, post-procedure patientcare and completion of appropriate orders. This tool is a scored checklist based largely on how much intervention is required by the supervising physician during the procedure, facilitating entrustability decisions. Validity evidence for the OBAT was obtained in a variety of clinical settings including the operating room, bronchoscopy suite and intensive care unit at the University of Ottawa and Queen's University. First- and second-year respirology, thoracic surgery and critical care fellows were recruited to participate. The first-year fellows were expected to have had some exposure to bronchoscopy but it was modest (<8 weeks), and the second-year fellows were expected to be approaching competency since they had completed 12 months of training. Over six months 148 forms were collected with 19 fellows and 15 faculty participating. The total OBAT score was derived by averaging the scores across all items. The 12 items on the scale were grouped into three subscales based on related content. Analysis of the data demonstrated that for any given trainee there were differences in the subscales and these therefore assessed different aspects of bronchoscopy competency. A generalizability analysis of the total OBAT ratings determined the reliability to be 0.92 with 7.5 forms/person and 0.82 with three forms/person. There was a significant difference in the mean total rating between first- and second-year fellows. Interrater reliability (IRR) and performance in a simulated setting were not explored.

The purpose of this study was to gather additional validity evidence for use of the OBAT to assess the readiness of novice fellows to progress towards independent performance of bronchoscopy. This included evaluation of: 1) the generalizability and interrater reliability (IRR) of the technical portion of the OBAT scores in simulated (cadaver) settings and 2) the correlation of scores between the OBAT and other measures of bronchoscopy performance in a high-fidelity simulator (Simbionix Bronch Mentor™) setting and a clinical setting. It is important to evaluate the OBAT in these settings as initial bronchoscopy training is typically done in a simulated setting and a measure of assessment should be performed prior to performance in a clinical setting.

We hypothesized that inter-observer reliability for scores and correlations to other bronchoscopy assessment tools would support the use of the OBAT for the assessment of pulmonary fellows in simulated settings

II. METHODS

A. The Setting

A single-center prospective study assessing the use of the OBAT in high-fidelity simulated settings with novice bronchoscopists was conducted during the Annual Midwest Introductory Bronchoscopy and Pleural Procedures Course in Rochester, Minnesota, in July 2018. This is a course for first-year fellows from across the United States Midwest region, to introduce them to basic bronchoscopy and pleural procedures. Faculty were sent material about the study and the OBAT tool prior to the course and invited to participate as raters, and a 20-minute presentation regarding the use of the tool and the study was provided to interested faculty prior to the start of the course. The tool was designed to require only minimal training for raters; this is the same amount of training that was provided to faculty during the initial OBAT study. During the course the fellows were instructed in basic bronchoscopy through the use of high-fidelity simulation on human cadavers. They were trained in the skills of airway inspection, bronchoalveolar lavage (BAL), endobronchial brushing, foreign-body localization, transbronchial needle aspiration and transbronchial lung biopsies.

Course participants received written information explaining the study before the course began and were invited to participate in the study. Fellows who agreed to participate provided demographic information (year in training, number of previous bronchoscopies, left or right handed) and verbal informed consent. If a participant declined consent this did not impact their ability to fully participate in the course and/or successfully complete the course. Individual assessment results were not shared with the fellows' training programs.

B. Assessment Protocol: OBAT performance and interrater reliability.

The assessment took place as the trainees rotated through five stations to learn each of the five core bronchoscopy skills. After completing each of three of the skills stations (BAL, endobronchial brushing, and foreign-body localization) the fellow was observed performing the procedure by two attending staff, one of whom was responsible for providing instructions and/or prompts as necessary during the procedure, as they would during a supervised bronchoscopy in a clinical setting. Both observers independently completed an OBAT immediately after completion of the procedure. As the pre- and post- procedure components were not performed, only the technical part of the OBAT was scored (items 4-10) (see Figure 1). The fellow was given formative feedback regarding their performance verbally using the OBAT form at the end of each station's assessment. Assessment forms were collected at the end of the course and scores entered into a database. All information was de-identified before analysis.

Figure 1. Ontario Bronchoscopy Assessment Tool –

Only the technical portion was scored during the assessment due to the simulated environment.

Ontario Bronchoscopy Assessment Tool						
Staff: (study number)			Date:			
Trainee: (study number)						
Relative complexity of procedure:	Low	Medium	High	Intubated Patient:	Yes	No
Samples Obtained / Interventions Performed						

Scale
1- "I had to take over"
2- "I had to talk the trainee through"
3- "I had to prompt the trainee from time to time"
4 -"I needed to be in the room just in case"
5- "I did not need to be there"

The purpose of this scale is to evaluate the trainee's ability to perform all activities related to bronchoscopy safely and independently. The scores provided should reflect the trainee's *ability to competently perform tasks relevant to bronchoscopy* and not be based on expectations related to level of training.
For intubated patients, omit questions 2 and 3.
If an item was not assessed because the supervisor had assumed control, "1" should be selected.

Pre-procedure planning					
1. Performs appropriate pre-procedure evaluation of patient, including review of pertinent investigations; discusses procedure with patient, obtains consent; communicates plans with bronchoscopy team	1	2	3	4	5
Sedation and Monitoring					
2. Selects and administers (or directs administration of) appropriate sedation and local anesthesia; attentive to patient's vitals and comfort during the procedure, modifies procedure and sedation appropriately	1	2	3	4	5
Technical					
3. Localizes / visualizes vocal cords / intubates trachea	1	2	3	4	5
4. Maintains good orientation /localization during procedure; correctly identifies bronchial anatomy and performs inspection in an orderly manner	1	2	3	4	5
5. Maintains good visualization of bronchi during procedure while avoiding excessive trauma to mucosa	1	2	3	4	5
6. Demonstrates good body and bronchoscopy mechanics	1	2	3	4	5
7. Able to obtain appropriate samples and/or perform appropriate intervention	1	2	3	4	5
8. Avoids complications if possible or recognizes and manages complications during procedure if they arise	1	2	3	4	5
9. Performs procedure efficiently (completes procedure in a timely manner without degradation in quality)	1	2	3	4	5
Diagnosis					
10. Recognizes abnormalities and appropriately describes bronchoscopy findings	1	2	3	4	5
Post-Procedure					
11. Develops post-procedure plan (provides appropriate verbal and written orders as appropriate); Ensures appropriate processing of samples (labels, samples, completes requisitions); Assesses for and manages post-procedure complications	1	2	3	4	5
12. Communicates bronchoscopic findings to patient and/or caregiver as appropriate; Documents procedure	1	2	3	4	5

C. Assessment Protocol: Relationships to other variables

The performance of Mayo fellows only was assessed immediately after the course on a high-fidelity virtual-reality bronchoscopy simulator (Symbionix Bronch Mentor™) using the Bronchoscopy Skills and Tasks Assessment Tool (BSTAT) and the technical portion of the OBAT.

Mayo fellows' OBAT scores were also obtained during live procedures during their subsequent clinical training and this was done by our interventional pulmonary fellow. The fellow performing the assessments was trained to use the OBAT during the bronchoscopy workshop along with other faculty. The first three OBAT scores obtained by the fellow during their clinical training (after the course) were compared to their simulator OBAT scores.

D. Analysis

A technical OBAT score was derived by calculating the mean score across all 7 items in the technical portion. Interrater reliability was calculated using intraclass coefficients with data from all three stations. Internal consistency reliability was calculated using Coefficient Alpha across the 7 technical items across all stations. Relationships to other variables were explored by comparing the total BSTAT scores with the total OBAT scores using Pearson's correlation coefficient. A Generalizability study was performed to explore facets contributing to the variability in the OBAT scores. Statistical analyses were performed using a statistical software package (IBM SPSS Statistics for Windows, version 25). Differences were considered significant when the p value <0.05. The testing protocol was considered exempt from institutional review by the Mayo Clinic and UIC Institutional Review Boards.

III. RESULTS

A total of 76 first year fellows and 40 faculty from 16 institutions attended the introductory bronchoscopy course. By the end of the course each trainee had completed a minimum of twenty simulated bronchoscopies. All but 4 of the trainees participating in this course were at a novice level (performed fewer than 5 clinical bronchoscopies prior to the course) (Table I). The study sample included 48 physicians: 44 first year fellows (PGY4), 2 senior fellows (PGY 6), and 2 thoracic surgery residents (PGY 5). Table I shows the average number of bronchoscopies previously performed by each group. Sixty-nine total procedures were observed by two raters. A total of 14 different faculty participated as raters at the three stations.

TABLE I

DEMOGRAPHICS OF THE PARTICIPATING TRAINEES

	# of prior bronchoscopies Average (SD) (min –max)
Junior fellows (PGY4) = 44	1.7 (3.8) (0-20)
Thoracic surgery residents (PGY 5) = 2	47.5 (3.5) (45-50)
Senior fellows (PGY6) = 2	121 (100) (50-192)
Total = 48	11.2 (34.8) (0-192)

A. Validity evidence – Internal Structure

The intraclass correlation of total technical scores for the 69 procedures performed on the cadaver simulator was ICC = 0.61, $p < 0.001$**.** The interrater reliability at each of the various stations is listed in Table II and demonstrates differences between the three simulation stations.

IRR was high at the station where a bronchoalveolar lavage (BAL) was performed (ICC = 0.69) and a foreign body (ICC = 0.80) was removed and lower at the station that required an endobronchial biopsy be performed (ICC = 0.44). To estimate the overall reliability of the OBAT as well as the estimate the proportion of variability attributable to different facets we performed a generalizability analysis resulting in a G-coefficient = 0.56 across the 3 stations (Table III). The variance attributable to the fellows was 11.7%, variance attributable to the stations was 25.9%, and raters nested in stations contributed 0% of the variance. Interactions between fellows and raters nested in each station contributed 27.6% of the variance.

In the second part of the study, fifteen trainees were assessed on a high-fidelity bronchoscopy virtual reality (VR) simulator (Symbionix, Bronch Mentor) using both the OBAT and BSTAT assessment tools. All but one of these trainees were novice bronchoscopists (<5 bronchoscopies performed clinically). The interrater reliability for the total technical OBAT scores on the VR simulator was ICC = 0.82, $p<0.001$. Internal consistency reliability (Cronbach's α) for the total technical OBAT ranged from 0.93 on the cadaver foreign-body station to 0.97 on the VR simulator. (Table II)

TABLE II

INTERRATER RELIABILITY OF THE OBAT (CADAVER SIMULATOR)

N= the number of learners observed at each station

Station	Mean (SD)	Range	ICC	Co-efficient alpha
Foreign Body (n=10)	2.92 (0.58)	2.07-3.5	0.80**	0.93
BAL (n=26)	2.62 (0.57)	1.36-3.5	0.69**	0.94
Endobronchial (n=33)	3.33 (0.57)	2.07-4.8	0.44**	0.95
Virtual reality (Simbionix) (n=15)	2.75 (0.16)	2.43-2.87	0.82**	0.97

*p<0.05; **p<0.001

BAL: bronchoalveolar lavage

TABLE III

GENERALIZABILITY ANALYSIS FOR OBAT (N=69 PROCEDURES)

Effect	VC	% VC	Interpretation
Fellow (f)	.089	11.7%	Variance due to differences between fellows
Station (s)	.198	25.9%	Variance due to differences in difficulty between stations
Rater (r) : Station (s)	.000	.0%	Variance due to difference between raters nested in stations
Item (i)	.000	.0%	Variance attributable to differences in difficulty between items
fs	.017	2.3%	Variance attributable to fellows' different performance in different stations
fr:s	.211	27.6%	Variance attributable to the interaction between fellows and raters nested in each station
fi	.000	.0%	Variance attributable to fellows' different performance on different items
si	.027	3.6%	Variance due to difference in difficulty of items across different stations
ri:s	.000	.0%	Variance due to differences between raters across different items
fsi	.047	6.2%	Variance due to differences in performance of fellows in different items in different stations
residual variance	.174	22.8%	Unexplained variance

G coefficient = 0.557

TABLE IV

INTERNAL CONSISTENCY FOR THE OBAT AND BSTAT
ON THE VIRTUAL REALITY SIMULATOR

OBAT	Mean	SD
Item 4	2.67	0.62
Item 5	2.83	0.72
Item 6	2.87	0.77
Item 7	2.77	0.73
Item 8	2.85	0.61
Item 9	2.43	0.68
Item 10	2.87	0.74

Cronbach's alpha = 0.97

B. Relationships to other variables

The correlation between total BSTAT scores and total technical OBAT scores (averaged across two raters) on the virtual reality simulator was Pearson's r (n=15) = 0.62, p=0.014.

There was no significant correlation between OBAT scores on the virtual reality simulator and OBAT scores for the first three clinical bronchoscopies (Table V). A logistic regression was performed controlling for weeks from the workshop to their first clinical bronchoscopy and no significant correlation was found.

TABLE V

CORRELATION OF OBAT SCORES OBTAINED DURING VR SIMULATION AND CLINICAL SETTING

Time	Correlation with VR simulation	*p*-value
1st bronch	0.12	0.746
2nd bronch	0.14	0.703
3rd bronch	0.21	0.570
end of 1st week of bronchoscopy training	0.77	0.628
4th week	0.00	0.999
Overall	0.11	0.466

IV. DISCUSSION

This study provides validity evidence for use of the OBAT to assess the readiness of novice fellows to progress towards performance of bronchoscopy in clinical settings, focusing on assessments using high-fidelity (cadaver) and virtual-reality simulators. Overall inter-rater reliability was high both by intraclass correlation and in the generalizability analysis, suggesting that it is acceptable to use a single trained rater per assessment. The IRR was lower at the endobronchial biopsy station than the others. This is likely due to the fact that this station was more technically difficult for new fellows and therefore there was more variability in performance and the rating there of. The G-study highlighted that the greatest sources of variance were the station and fellow-rater-station interactions (25% and 27% respectively). Relatively little of the variance was due to the difference between raters at a given station. The differences in performance at different stations can be related to the cadaver, the fellow, and the task that is to be performed and therefore an accurate assessment requires multiple bronchoscopies to be observed.

The substantial correlation between OBAT and BSTAT scores (r-0.62) on the VR simulator provides additional support for use of the OBAT in a high-fidelity virtual reality simulated setting. The BSTAT was developed for use in a simulated setting and is a checklist. The OBAT was designed for use in a clinical context and the scoring is based on an entrustment scale. When assessing a trainee on a virtual reality simulator it may be difficult for the faculty to recognize when they would intervene as there are no concerns for patient safety. The correlation between BSTAT and the OBAT scores suggests that an entrustment-type scale can be deployed in a simulated setting as well. This is useful as the same tool can then be used throughout the course of bronchoscopy training.

The high internal consistency of OBAT scores (Coefficient Alpha = 0.97) is surprising given the fact that we included only the technical portion of the OBAT and each of these items should assess a different aspect of the task. The high internal consistency that was noted may be due in part to the fact that all the fellows were all novices, and don't know how to perform any part of a bronchoscopy. As they progress with their procedural skills they may develop skills in some areas quicker than others and the internal consistency would then be lower. In addition, all the fellows were novices and it could be with a more heterogeneous group that more variation would be observed across those subtasks.

There was no correlation between the scores of the OBAT on the virtual reality simulator and in the clinical context. Several factors may have contributed to this finding. Each of the fellows performed at least two additional simulator cases between the initial VR assessment and their first clinical bronchoscopy, and this individually-variable additional practice may account for the poor correlation of scores. Second, the clinical assessment was done by a more senior-level fellow (interventional pulmonary fellow), who has less experience in assessment of trainees. Finally, we were able to get clinical data for only a small number of fellows (N=10) and the numbers may have been too low to detect a significant correlation.

There are several limitations to this study. First, all participants were first-year fellows and therefore there was limited difference in skill level among trainees. This reduced the range of responses and may account for why the variance in the fellows' scores was substantially lower than in the clinical setting. Second, the variability between stations was high and additional observations done across more stations would be helpful to get a better assessment of competence. This is an important finding of the study as it emphasizes the need to evaluate performance over multiple stations to obtain a reliable assessment of competency. A third

limitation of this study is that we only assessed the technical portion of the OBAT. Therefore, we cannot comment on the validity of the pre procedural and post procedural aspects of the OBAT.

V. SUMMARY

This is the first study showing validity evidence for the OBAT in high-fidelity simulated settings. The OBAT demonstrated excellent interrater reliability and correlation to another bronchoscopy assessment tool, supporting its use for the purpose of assessment of novice fellows in a cadaver or simulated setting.

CITED LITERATURE

Davoudi, M., K. Osann, and H. G. Colt. "Validation of Two Instruments to Assess Technical Bronchoscopic Skill Using Virtual Reality Simulation." *Respiration* 76, no. 1 (2008): 92-101. https://doi.org/10.1159/000126493. https://www.ncbi.nlm.nih.gov/pubmed/18408359.

Epstein, M. L., and G. M. Brosvic. "Immediate Feedback Assessment Technique: Multiple-Choice Test That "Behaves" Like an Essay Examination." *Psychol Rep* 90, no. 1 (Feb 2002): 226. https://doi.org/10.2466/pr0.2002.90.1.226. https://www.ncbi.nlm.nih.gov/pubmed/11898987.

Epstein, R. M. "Assessment in Medical Education." *N Engl J Med* 356, no. 4 (Jan 25 2007): 387-96. https://doi.org/10.1056/NEJMra054784. https://www.ncbi.nlm.nih.gov/pubmed/17251535.

Ernst, A., G. A. Silvestri, D. Johnstone, and Physicians American College of Chest. "Interventional Pulmonary Procedures: Guidelines from the American College of Chest Physicians." *Chest* 123, no. 5 (May 2003): 1693-717. https://www.ncbi.nlm.nih.gov/pubmed/12740291.

"Guidelines for Competency and Training in Fiberoptic Bronchoscopy. Section on Bronchoscopy, American College of Chest Physicians." [In eng]. *Chest* 81, no. 6 (Jun 1982): 739.

Knight, R. K., and S. W. Clarke. "An Analysis of the First 300 Fibreoptic Bronchoscopies at the Brompton Hospital." *Br J Dis Chest* 73, no. 2 (Apr 1979): 113-20. https://www.ncbi.nlm.nih.gov/pubmed/534601.

Konge, L., K. R. Larsen, P. Clementsen, H. Arendrup, C. von Buchwald, and C. Ringsted. "Reliable and Valid Assessment of Clinical Bronchoscopy Performance." *Respiration* 83, no. 1 (2012): 53-60. https://doi.org/10.1159/000330061. https://www.ncbi.nlm.nih.gov/pubmed/21912087.

Ouellette, D. R. "The Safety of Bronchoscopy in a Pulmonary Fellowship Program." [In eng]. *Chest* 130, no. 4 (Oct 2006): 1185-90. https://doi.org/10.1378/chest.130.4.1185.

Pastis, N. J., P. J. Nietert, and G. A. Silvestri. "Variation in Training for Interventional Pulmonary Procedures among Us Pulmonary/Critical Care Fellowships: A Survey of Fellowship Directors." [In eng]. *Chest* 127, no. 5 (May 2005): 1614-21. https://doi.org/10.1378/chest.127.5.1614.

Voduc, N., N. Dudek, C. M. Parker, K. B. Sharma, and T. J. Wood. "Development and Validation of a Bronchoscopy Competence Assessment Tool in a Clinical Setting." [In eng]. *Ann Am Thorac Soc* 13, no. 4 (Apr 2016): 495-501. https://doi.org/10.1513/AnnalsATS.201508-548OC.

Wahidi, M. M., G. A. Silvestri, R. D. Coakley, J. S. Ferguson, R. W. Shepherd, L. Moses, J. Conforti, *et al.* "A Prospective Multicenter Study of Competency Metrics and Educational Interventions in the Learning of Bronchoscopy among New Pulmonary Fellows." *Chest* 137, no. 5 (May 2010): 1040-9. https://doi.org/10.1378/chest.09-1234. https://www.ncbi.nlm.nih.gov/pubmed/19858234.

VITA

NAME Darlene R. Nelson

EDUCATION

North Park University, Chicago, Illinois - BA, Biology	1997 - 2001
University of Illinois College of Medicine, Rockford, Illinois - MD	2001 - 2005
Mayo School of Graduate Medical Education, Mayo Clinic College of Medicine, Rochester, Minnesota - Resident	07/2005 - 06/2008
Mayo School of Graduate Medical Education, Mayo Clinic College of Medicine, Rochester, Minnesota - Chief Resident	07/2008 - 06/2009
Mayo School of Graduate Medical Education, Mayo Clinic College of Medicine, Rochester, Minnesota - Fellow, Pulmonary and Critical Care Medicine	07/2009 - 09/2012
Mayo School of Graduate Medical Education, Mayo Clinic College of Medicine, Rochester, Minnesota - Chief Pulmonary Fellow	07/2011 - 07/2012
University of Illinois College of Medicine at Chicago, Chicago, Illinois - MHPE	07/2014 - Present

CERTIFICATION

American Association of Bronchology and Interventional Pulmonology (AABIP) Interventional Pulmonology	2016 - Present
American Board of Internal Medicine (ABIM)	
Internal Medicine	2008 - Present
Pulmonary Disease	2011 - Present
Critical Care Medicine	2012 - Present
United States Medical Licensing Examination (USMLE)	
Step I	2003 - Present
Step II Clinical Knowledge	2004 - Present
Step II Clinical Skills	2004 - Present
Step III	2006 - Present
Mayo Clinic Quality Academy	
Mayo Clinic Quality Fellow: Bronze Level Certification	2010
Mayo Clinic Quality Fellow: Silver Level Certification	2014

LICENSURE

Minnesota	(Medical)	2006 - Present

HONORS AND AWARDS

Lincoln Laureate Award - North Park University, Chicago, Illinois	2000
Beta Beta Beta Biology Honors Society - North Park University, Chicago, Illinois	2001
Oustanding Senior of the Year - North Park University, Chicago, Illinois	2001
Senior Female Athlete of the Year - North Park University, Chicago, Illinois Cross country/track & field	2001
Suma Cum Laude - North Park University, Chicago, Illinois	2001
Avery Brundage Scholarship - University of Illinois College of Medicine, Rockford, Rockford, Illinois	2003 - 2004
James Scholar Independent Honors Research Program - University of Illinois College of Medicine, Rockford, Rockford, Illinois	2005
Best Written Clinical Vignette - A Severe Case of ARDS Secondary to Babesiosis - Regional Meeting, American College of Physicians, Minneapolis, Minnesota	11/2006
Chief Resident - Mayo Graduate School of Medicine, Mayo Clinic College of Medicine	2008 - 2009
Outstanding Senior Award - Mayo Graduate School of Medicine, Mayo Clinic College of Medicine	2008
Chief Fellow - Mayo Graduate School of Medicine, Mayo Clinic College of Medicine	2011 - 2012
Best Case Presentation- Intravascular pulmonary lymphoma - American College of Chest Physicians (CHEST), Honolulu, Hawaii	10/2011
Teacher of the Year for Pulmonary and Critical Care Medicine - Mayo Fellows Association - Mayo Fellows and Residents Association, Rochester, Minnesota	02/2019
Mid-Career Educator Award - Association of Pulmonary and Critical Care Medicine Program Directors	03/2020 - Present

PREVIOUS PROFESSIONAL POSITIONS AND MAJOR APPOINTMENTS

Instructor of Medicine - Mayo Clinic College of Medicine and Science	10/2008 - 09/2015
Senior Associate Consultant - Division of Pulmonary and Critical	09/2012 - 09/2015

Care Medicine, Department of Internal Medicine, Mayo Clinic, Rochester, Minnesota

Education Coordinator for Pulmonary Rotations - Department of Internal Medicine, Mayo Clinic, Rochester, Minnesota — 07/2013 - 07/2015

Associate Program Director - Pulmonary and Critical Care Medicine Fellowship, Division of Pulmonary and Critical Care Medicine, Department of Internal Medicine, Mayo Clinic, Rochester, Minnesota — 07/2013 - 09/2019

Block Leader - Year II Respiratory Pathophysiology Course, Mayo Medical School, Mayo Clinic College of Medicine and Science, Rochester, Mayo Clinic School of Medicine, Minnesota — 08/2015 - 01/2020

PROFESSIONAL MEMBERSHIPS AND SOCIETIES

Alliance for Academic Internal Medicine, member
American College of Chest Physicians, member
American College of Physicians, member
American Medical Association, associate member
American Thoracic Society, member
Christian Medical and Dental Association, member
Minnesota Medical Association, member
Society of Critical Care Medicine, member

TEACHING

Evidence-Based Medicine Curriculum — 07/2008 - 06/2009

Morbidity & Mortality Conference — 07/2008 - 06/2009

Quality Improvement Curriculum — 07/2008 - 06/2009

Airway Workshop — 07/2010 - 06/2011

Pulmonary and Critical Care Lectures to Internal Medicine Residents
Internal Medicine Residency Core Curriculum
Rochester Minnesota — 11/2012 - Present

Fundamentals of Critical Care Support
Society of Critical Care Medicine — 07/2013 - Present

Annual Midwest Introductory Bronchoscopy and Pleural Procedures Course
Introductory Bronchoscopy Course for first year pulmonary and critical care fellows from 18 institutions across the country
Annual Midwest Introductory Bronchoscopy and Pleural Procedures Course
Rochester Minnesota — 07/2014 - 07/2016

Enhancing Learning in Medicine - Faculty
Mayo Clinic - Internal Medicine Residency — 07/01/2015 - Present

Rochester Minnesota

Course Director — 08/2015 - Present
Pulmonary Block for second year medical students
Mayo Medical School
R0chester Minnesota

Course Director - Annual Midwest Introductory Bronchoscopy and Pleural Procedures Course — 07/01/2017 - Present
Course Director for annual introductory course that hosts 18 institutions, 80 trainees and 40 faculty
Annual Midwest Introductory Bronchoscopy and Pleural Procedures Course
Rochester Minnesota

Bronchoscopy in the ICU — 05/03/2019
Basic Bronchoscopy Course for ICU providers
American College of Chest Physicians
Chicago, Illinois

RESEARCH GRANTS AWARDED

Co-Investigator — 04/2017 - 04/2019
Randomized, Double-Blind, Placebo-Controlled, Phase 3 Study to Evaluate Safety & Efficacy CCX168 (Avacopan) in Patients with ANCA-Associated Vasculitis Treated Concomitantly with Rituximab or Cyclophosphamide/Azathioprine. Funded by ChemoCentryx, Inc.. (CL010-168)

Mayo Clinic

Program Director / Principal Investigator — 03/2013 - 03/2015
Pulmonary/Critical Care Fellowship Mentoring Program. Funded by SGP - Small Grants Program <$10K

Program Director / Principal Investigator — 01/2016 - 12/2016
Mindfulness Training and Its Impact on Multidisciplinary Mock Code Training . Funded by Endowment for Education Research Award (EERA)

Co-Investigator — 04/2014 - 04/2016
Prospective Evaluation of the Prevalence of Infectious Pathogens in Culture-Negative, Non-Specific Pleuritis Patients. Funded by SGP - Small Grants Program <$10K

PUBLICATIONS

Peer Reviewed Journals

Carey, E. J., V. N. Iyer, D. R. Nelson , J. H. Nguyen, M. J. Krowka."Outcomes for Recipients of Liver Transplantation for Alpha-1-Antitrypsin Deficiency-Related Cirrhosis." *Liver Transpl*. 19, no. 12 (Dec 2013): 1370-6. DOI: 10.1002/lt.23744.

Cawcutt, K. A., M. M. Bhatti, D. R. Nelson."Pleural Fluid Infection Caused by Dietzia Cinnamea." *Diagn Microbiol Infect Dis.* 85, no. 4 (Aug 2016): 496-67. DOI: 10.1016/j.diagmicrobio.2016.04.007.

Chae, J., R. Kern, D. Nelson, J. Mullon. "Diffuse Large B Cell Lymphoma with Superimposed Lung Abscess: Potential Role for Intracavitary Fibrinolytic Therapy Through a Percutaneous Drain to Facilitate Lung Abscess Drainage." *BMJ Case Rep*. 11, no. 1 (Nov 2018). DOI: 10.1136/bcr-2018-225670.

Duncan, D. R., T. I. Morgenthaler, J. H. Ryu, C. E. Daniels. "Reducing Iatrogenic Risk in Thoracentesis: Establishing Best Practice Via Experiential Training in a Zero-Risk Environment." *Chest* 135, no. 5 (May 2009): 1315-1320. DOI: 10.1378/chest.08-1227.

Durani, U, A. Gallo de Moraes, J. Beachey, D. Nelson, S. Robinson, N. S. Anavekar. "Epithelioid Angiosarcoma: A Rare Cause of Pericarditis and Pleural Effusion." *Respir Med Case Rep*. 24 (Apr 2018):.77-80. DOI: 10.1016/j.rmcr.2018.04.008.

Frazee, E. N., S. J. Lee, E.A. Kalimullah, H.A. Personett, D. R. Nelson. "Circulatory Support with Venoarterial ECMO Unsuccessful in Aiding Endogenous Diltiazem Clearance after Overdose." *Case Rep Crit Care* (Aug 2014): 969578. DOI: 10.1155/2014/969578.

Havyer, R. D., M. T. Wingo, N. I. Comfere, D. R. Nelson, A. J. Halvorsen, F. S. McDonald, D. A. Reed. "Teamwork Assessment in Internal Medicine: A Systematic Review of Validity Evidence and Outcomes." *J Gen Intern Med*. 29, no. 6 (Jun 2014):894-910. DOI: 10.1007/s11606-013-2686-8.

Havyer, R. D., D. R.Nelson, M. T. Wingo, N. I. Comfere, A. J. Halvorsen, F. S. McDonald, D. A. Reed. "Addressing the Interprofessional Collaboration Competencies of the Association of American Medical Colleges: A Systematic Review of Assessment Instruments in Undergraduate Medical Education." *Acad Med*. 91, no. 6 (Jun 2016):865-88. DOI: 10.1097/ACM.0000000000001053.

Kelm, D. J., J. H. Skalski, D. R. Nelson, K. B. Kashani, A. S. Lee, L. J. Wesselius, K. Ramar. "Attributes Influencing the Selection of Fellowship Programs by Pulmonary and Critical Care Applicants: A Pilot Study." *Ann Am Thorac Soc.* 13, no. 4 (Apr 2016):572-74. DOI: 10.1513/AnnalsATS.201601-032LE.

Kelm, D. J., J. L. Ridgeway, B. L. Gas, M. Mohan, D. A. Cook, D. R. Nelson, R. P. Benzo. "Mindfulness Meditation and Interprofessional Cardiopulmonary

Resuscitation: A Mixed-Methods Pilot Study." *Teach Learn Med*. 30, no. 4 (Oct-Dec 2018):433-43. DOI: 10.1080/10401334.2018.1462186.

Navin, P. J., M. L. White, F. C. Nichols, D. R. Nelson, J. J. Mullon, J. S. McDonald, T. D. Atwell, M. R. Moynagh. "Periprocedural Major Bleeding Risk of Image-Guided Percutaneous Chest Tube Placement in Patients with an Elevated International Normalized Ratio." *J Vasc Interv Radiol.* 30, no. 11(Nov 2019):1765-68. DOI: 10.1016/j.jvir.2019.07.002.

Nelson, D. R., M. C. Aubry, C. E. Daniels. "Intravascular Lymphoma as a Cause of Respiratory Failure." *J Thorac Oncol.* 7, no. 12 (Dec 2012):e34-e35. DOI: 10.1097/JTO.0b013e31826bb8e6.

Nelson, D. R., G. B. Johnson, R. Cartin-Ceba, U. Specks. "Characterization of F-18 Fluorodeoxyglucose PETCT in Granulomatosis with Polyangiitis." *Sarcoidosis Vasc Diffuse Lung Dis.* 32, no. 4 (Jan 2016): 342-52.

Nguyen, D. L., S. Khambatta, J. B. Eickstaedt, D. R. Nelson. "A 40-year-old Man with Spells of Generalized Weakness and Paresthesias." *Cleve Clin J Med*. 77, no. 2 (Feb 2010):117-22. DOI: 10.3949/ccjm.77a.09068.

Pang, Y. P., M. Casal Moura, G. E. Thompson, D. R. Nelson, A. M. Hummel, D. E. Jenne, D. Emerling, W. Volkmuth, W. H. Robinson, U. Specks. "Remote Activation of a Latent Epitope in an Autoantigen Decoded with Simulated B-Factors." *Front Immunol*. 10 (2019):2467. DOI: 10.3389/fimmu.2019.02467.

Patel, P. P., S. Singh, T. D. Atwell, R. Kashyap, R. M. Kern, J. J. Mullon, D. R. Nelson. "The Safety of Ultrasound-Guided Thoracentesis in Patients on Novel Oral Anticoagulants and Clopidogrel: A Single-Center Experience." *Mayo Clin Proc*. 94, no. 8 (Aug 2019):1535-1541. DOI: 10.1016/j.mayocp.2019.01.046.

Patel, P. P., D. R. Nelson. "Hard to Swallow: A Mediastinal Hematoma Causing Esophageal Compression After Endobronchial Ultrasound-guided Transbronchial Needle Aspiration." *J Bronchology Interv Pulmonol*. 27, no. 1 (Jan 2020):e1-e3. DOI: 10.1097/LBR.0000000000000598.

Sakata, K. K., D. R. Nelson, D. E. Midthun. "Pulmonary Hemorrhage Treated with Oxidized Regenerated Cellulose." *J Bronchology Interv Pulmonol* 24, no. 3 (Jul 2017):42-44. DOI: 10.1097/LBR.0000000000000390.

Sakata, K. K., F. Nasim, D. N. Schiavo, D. R. Nelson, R. M. Kern, J. J. Mullon. "Methylene Blue for Bronchopleural Fistula Localization." *J Bronchology Interv Pulmonol.* 25, no. 1 (Jan 2018):63-66. DOI: 10.1097/LBR.0000000000000423.

Sakata, K. K., D. R. Nelson, J. J. Mullon, D. E. Midthun, E. S. Edell, R. M. Kern. "Paclitaxel-coated Balloon Dilation for Central Airway Obstruction." *Respir Med Case Rep*. 24 (2018):129-132. DOI: 10.1016/j.rmcr.2018.05.011.

Sakata, K. K., D. E Midthun, J. J. Mullon, R. M. Kern, D. R. Nelson, E. S. Edell, D. N. Schiavo, J. R. Jett, M. C. Aubry. "Comparison of Programmed Death Ligand-1 Immunohistochemical Staining Between Endobronchial Ultrasound Transbronchial Needle Aspiration and Resected Lung Cancer Specimens." *Chest* 154, no. 4 (Oct 2018):827-37. DOI: 10.1016/j.chest.2018.07.017.

Szostek, J. H., M. L. Wieland, L. L. Loertscher, D. R. Nelson, C. M. Wittich, F. S. McDonald, J. C. Kolars, D. A. Reed. "A Systems Approach to Morbidity and Mortality Conference." *Am J Med*. 123, no. 7 (Jul 2010):663-68. DOI: 10.1016/j.amjmed.2010.03.010.

Wieland, M. L., L. L. Loertscher, D. R. Nelson, J. H. Szostek, R. D. Ficalora. "A Strategy to Reduce Interruptions at Hospital Morning Report." *J Grad Med Educ*. 2, no. 1 (Mar 2010):83-4. DOI: 10.4300/JGME-D-09-00084.1.

Wingo, M. T., R. D. Havyer, N. I. Comfere, D. R. Nelson, D. A. Reed. "Interprofessional Collaboration Milestones: Advocating for Common Assessment Criteria in Graduate Medical Education." *BMC Med Educ*. 14, no. 15 (Sep 2015):149. DOI: 10.1186/s12909-015-0432-0.

Youssef, S. J., D. M. Orbelo, K. K. Sakata,T. M. Zimmermann, R. L. Pittelko, D. R. Nelson, D. E. Midthun, E. S. Edell, D. C. Ekbom. "Dysphonia Due to Vocal Cord Injury After Rigid Bronchoscopy: A Case Study With 1-Year Bronchoscopic Follow-up." *J Bronchology Interv Pulmonol.* 26, no. 4 (Oct 2019):e52-e55. DOI: 10.1097/LBR.0000000000000587.

Book Chapters

Nelson, D. R, Williams BP, Scanlon P. Chapter 34: "Sports Pulmonology." In: *Sports Medicine: Study Guide and Review for Boards.* 2011

Nelson, D. R, Specks U. "Wegener's Granulomatosis: Pulmonary Manifestations and Treatment Review." In: *European Respiratory Monograph*. 2012

Nelson, D. "Pleural Disease." In: *Pulmonary Medicine: MKSAP*. July 2015.

Nelson, D. R. Williams BP, Scanlon P. "Sports Pulmonology." In: *Sports Medicine: Study Guide and Review for Boards*, Mark A. Harrast; Jonathan Finnoff., eds. 2nd Edition.

Nelson, D. R. "Lung Cancer and Pleural Disease." In: M*edical Knowledge Self-Assessment Program 18 - American College of Physicians*. 2018.