Journal of Medical Systems (2023) 47:51
https://doi.org/10.1007/s10916-023-01946-z

ORIGINAL PAPER

A Quality Improvement Study Designed to Optimize Scheduling Geographic/Site Preferences Among Anesthesia Professionals Utilizing Decision Support Tool Assistance

Mark A. Deshur[1,2] · Noah Ben-Isvy[1,3] · Chi Wang[1] · Mohammed Minhaj[1,2] · Steven Greenberg[1,2]

Received: 5 September 2022 / Accepted: 29 March 2023 / Published online: 25 April 2023

Abstract

This is a quality improvement pilot study comparing percentages of anesthesia professionals receiving their first choice of workplace location both pre-, and post-implementation of an electronic decision support tool for anesthesia-in-charge schedulers. The study evaluates anesthesia professionals who use the electronic decision support tool and scheduling system at four hospitals and two surgical centers within NorthShore University HealthSystem. The subjects in the study are those anesthesia professionals that work at NorthShore University HealthSystem and are subject to being placed in their desired location by anesthesia schedulers who use the electronic decision support tool. The primary author developed the current software system enabling the electronic decision support tool implementation into clinical practice. All anesthesia-in-charge schedulers were educated during a three-week time period via administrative discussions and demonstrations on how to effectively operate the tool in real time. The total numbers and percentage of 1st choice of location selection by anesthesia professionals were summarized each week using interrupted time series Poisson regression. Slope before intervention, slope after intervention, level change, and slope change were all measured over 14-week pre- and post- implementation periods. The level of change (difference in percentage of anesthesia professionals who received their first choice) was statistically ($P<0.0001$) and clinically significant when comparing the historical cohorts of 2020 and 2021 to the 2022 intervention group weeks. Therefore, the implementation of an electronic decision support scheduling tool resulted in a statistically significant increase in those anesthesia professionals receiving their first-choice workplace location. This study provides the basis for further investigating whether this specific tool may improve anesthesia professional satisfaction within their work-life balance by enhancing workplace geographic/site choice.

Keywords Decision · Support · Optimization · Location preference · Anesthesia professionals

✉ Steven Greenberg
sgreenberg@northshore.org

Mark A. Deshur
meshur@mac.com

Noah Ben-Isvy
NBen-Isvy@northshore.org

Chi Wang
CWang3@northshore.org

Mohammed Minhaj
MMinhaj@northshore.org

[1] NorthShore University HealthSystem, 2650 Ridge Ave., Evanston, IL 60201, USA

[2] Pritzker School of Medicine, University of Chicago, 5841 S. Maryland Ave, Chicago, IL 60637, USA

[3] University of Illinois Urbana-Champaign, Champaign, IL, USA

Introduction

The ability to have choice in clinical geographic location assignments based on individual preferences has the potential to improve healthcare provider satisfaction[1]. Past literature has established an association between scheduling practices and healthcare provider job satisfaction [1–3]. In recent years, electronic decision support tools have emerged as a method for scheduling advancement in healthcare management to provide an efficient tool to place providers in the appropriate clinical environment [4, 5]. In addition, previous studies have also found success in applying electronic decision support tools to determine fair end of shift relief among anesthesiologists [6, 7].

No study to date has investigated the use of an electronic decision support tool for anesthesia geographic/site

preference accommodation within a major healthcare system. We sought to further understand the value of an anesthesia scheduling decision support tool to optimize anesthesia professional choice of anesthesia work location. This interventional quality improvement pilot study investigated the level change of the percentage of anesthesia professionals who received their first-choice work location both pre- and post-implementation.

Materials and methods

The outlined quality improvement study observed trends in anesthesia professional scheduling at six locations within the NorthShore University HealthSystem, a nine-hospital system primarily located in the northshore of Chicago. IRB consent was waived as this was a quality improvement investigation. Historically (starting in 2020), each participant was given the opportunity to rank four hospital locations and two surgery centers by preference, while also indicating the strength of preference next to each ranking. The strength of preference could be designated as one of three options: green (send me anytime), yellow (send me only if needed), or pink (please try not to send me) (Fig. 1).

A 14-week pre-implementation period occurred between September-December 2021. During the pre-implementation period, a prepopulated, static preference list was presented to the anesthesia-in-charge schedulers (AICs) for each provider with no strength of preference designation, which was the previous scheduling practice before implementation of this present decision support tool since 2017. The AICs could see ordered rankings prior to daily scheduling and incorporate them into assignments. The post- implementation period was also 14-weeks (January 2022- April 2022), immediately after the implementation of the electronic decision support tool. During a 3-week period between the two time periods of comparison, AICs received administrative training in implementing the newly developed decision support tool. There were six individual AICs responsible for making the assignments during both study periods. All of these AICs had at least 4-5 years of experience using the scheduling software.

The scheduling software user interface can fundamentally be broken down into two main components: (Fig. 1) the anesthesia professional user interface and (Fig. 2) the AIC user interface. All anesthesia professionals have access to the user interface scheduling software and frequently access it to view upcoming shift schedules. Anesthesia professionals were free to document and change their preferences at any time during the pre and post study periods. Indication of location preference and strength of preference were documented in this location as seen in Fig. 1.

The AIC user interface is used by AICs to make work assignments via a real-time scheduling dashboard. This daily dashboard shows all of the locations that will need to be staffed, alongside all of the available anesthesia providers. Staff preferences were displayed in the AIC dashboard before any assignments were made to offer suggestions on where to assign providers. Further, as assignments were being made, the suggestions were updated in real-time to suggest changes that would improve provider geographic/site preference. The decision support tool was added to the dashboard to offer real-time feedback to the AICs through recommendations to optimize location preference as seen in Fig. 2. The algorithm analyzes all possible permutations of provider locations and recommends changes that would improve overall provider preferences. These recommendations are presented to the AICs for review and approval. Further information about the algorithm can be acquired by contacting the primary author.

At the time of implementation of the scheduling software, 82 anesthesia professionals took part in the preference exercise. Typically, an email was sent to this group of anesthesia

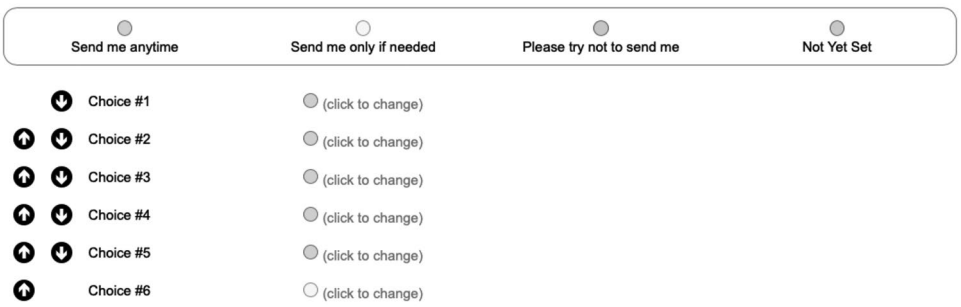

Fig. 1 Depicts an actual screenshot of what the anesthesia professionals see when ranking their geographic/site preferences. This is an example of ordered location rankings with strength of preference presented to the anesthesia professional user interface. The choice #1 would be equivalent to the anesthesia professional's first choice of work location or geographic site preference

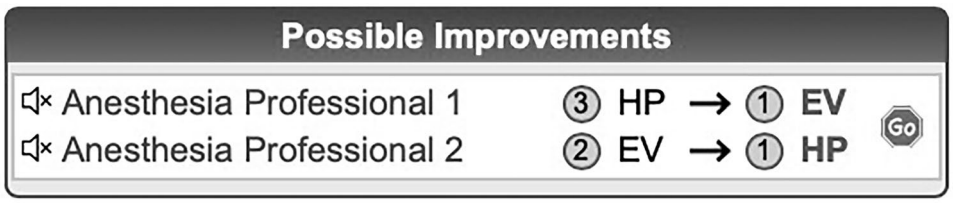

Fig. 2 An example of an electronic decision support guided recommendation that optimizes location preference and is presented in the AIC user interface during scheduling. Anesthesia Professionals 1 and 2 are two different providers. HP = Highland Park Hospital, EV = Evanston Hospital. The circled numbers indicate the anesthesia professional specific location preferences. For instance, Anesthesia Professional 1 had Highland Park Hospital as their 3rd choice and Evanston Hospital as their first choice. Therefore, a swap was made between Anesthesia Professionals 1 and 2 and Anesthesia professional 2 received their first choice as Highland Park and Anesthesia professional 1 received their first choice as Evanston Hospital

professionals announcing that a tool was available to them to choose location preferences, and a reminder prompt was added to the anesthesia professional interface suggesting designation of preference upon login. All 82 anesthesia professionals in this cohort at NorthShore University HealthSystem selected location preferences for the six locations. Of the 82 anesthesia professionals, 70 anesthesia professionals in this cohort additionally documented strength of preference next to each ranking.

Data analysis

The primary endpoint was location preferences. The total numbers and percentage of 1st choice of location selection by anesthesia professionals were summarized each week during the 14-week pre- implementation (9/27/21-12/27/21) and post-implementation (1/24/22-4/25/22) periods. In addition, post-implementation data were compared with two historical controls (1/27/20-4/27/20 and 1/25/21-4/26/21) of the same period of the time from the previous years to determine any historical trends. Location preferences were reported using percentages and were compared using chi-square test between pre- and post-implementation periods. We conducted an interrupted time series analysis [8] to examine the level change and slope change of the weekly 1st choice of location selection rate between the pre-implementation and post-implementation periods using Poisson regression with the total number of location selections each week as the offset variable. A similar model was also performed to compare data between post-implementation and two historical controls. We assessed autoregression by examining the plot of residuals and the partial autocorrelation function and conducting the BreuschGodfrey test [9]. A two-sided p value of less than 0.05 was considered statistically significant. All analyses were conducted using SAS 9.4 (Statistical Analysis System, Cary, NC).

Results

The percentage of 1st choice of location selection increased significantly from 50.9% to 63.9% ($p< .0001$) between pre and post implementation periods. Figure 3 illustrates the percentage of weekly 1st choice of location selection by anesthesia professionals immediately before and after implementation of the scheduling decision support tool. Using interrupted time series analysis, comparisons were made between pre- and post- implementation periods with regards to the slope, the level change, and the slope change (Table 1). There was a significant difference in level change when comparing pre- vs. post-implementation of those anesthesia professionals achieving their first choice in work location ($p <.0001$). Both slopes were not significant during pre ($p=0.7901$) and post-intervention ($p=0.9938$) periods. In addition, there was no difference in the slope change between both groups ($p=0.8428$).

Figure 4 represents a comparison of the percentage of 1st choice of location selection by anesthesia professionals between the historical and intervention cohorts over the same period of time. Comparison of the two historical cohorts demonstrated no statistical difference in the level of change. The slope before and after intervention and the slope change were all not statistically significant between any of the cohorts evaluated. The level change of the percentage of anesthesia professionals receiving their 1st choice after implementation of the new electronic AIC decision support tool was significantly different ($p < 0.0001$) when compared to the historical cohorts (Table 2).

Discussion

This interventional quality improvement study investigated the effects of implementing an electronic decision support tool on anesthesia professional work location preference.

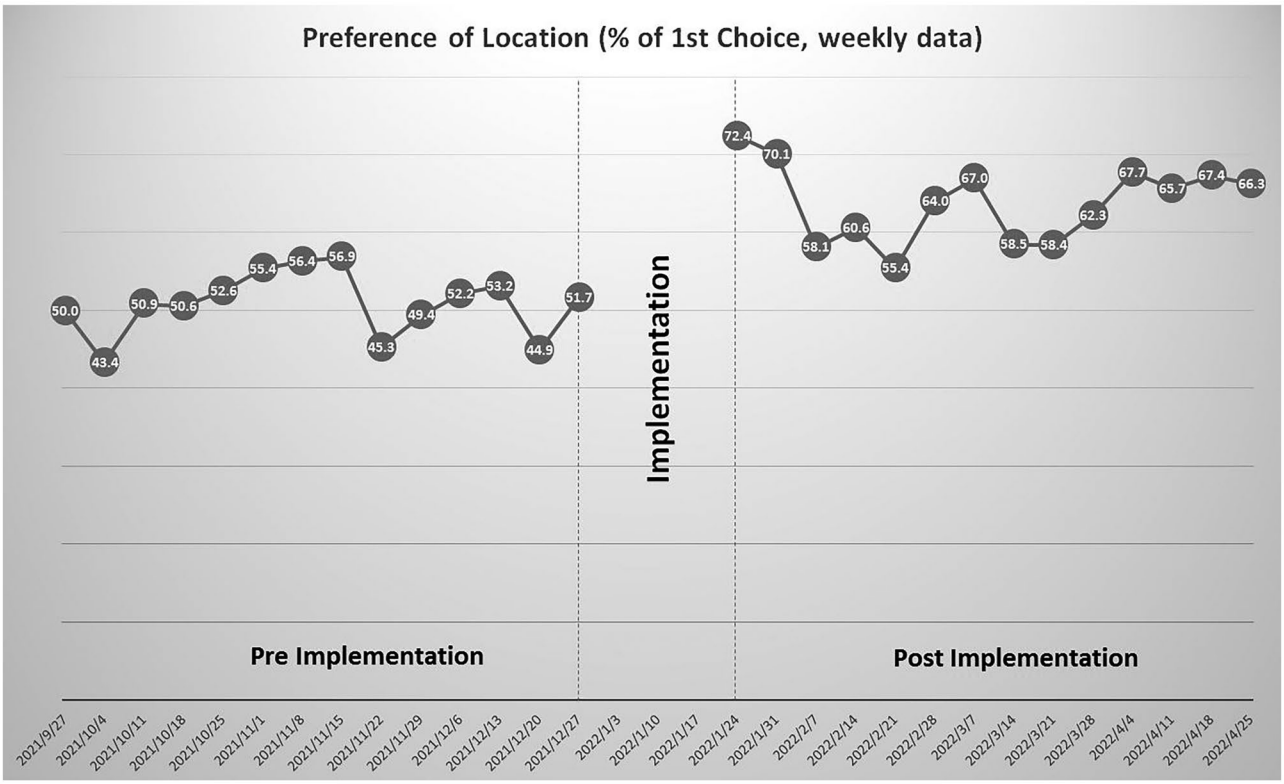

Fig. 3 Percentage of 1st Choice of Location Selection Immediately Before and After Intervention

This study observed a statistically significant level change of those anesthesia professionals receiving their number one location preference post-implementation of an electronic scheduling decision support tool when compared with a pre-implementation period, and compared to two historical control cohorts. In addition, a majority of the workforce voluntarily participated in selecting their preferences for work locations. This suggests that this specific anesthesia professional group desired choice as it relates to workplace location. Providing choice to healthcare professionals may indeed reduce the risk of job dissatisfaction [1–3].

Additionally, the ability to change location preference in the anesthesia professional user interface offers the opportunity for dynamic preference accommodation. During the pre-implementation period, 14 anesthesia professionals changed their locations preferences a total number of 16 times. In comparison, during the post-implementation period, 66 anesthesia professionals changed their locations preferences a total number of 110 times. Each individual provider changed location preference anywhere from 1 to 7 times throughout the post-implementation period. The dramatic difference in location preference changes may be explained by the fact that the departmental Vice Chair of Operations, sent out an email notification to the anesthesia professionals requesting that they update their location preferences. In addition, this was also emphasized at our Departmental Meetings.

Table 1 Interrupted Time Series Poisson Regression

Parameter	β	SE	IRR	p value
Slope before intervention	0.0020	0.0074	1.0020	0.7901
Slope after intervention	0.0001	0.0062	1.0001	0.9938
Level change	0.2220	0.0329	1.2486	< 0.0001
Slope change	−0.0019	0.0096	0.9981	0.8428

While implementation of the decision support tool outlined in the present study occurred in 2022, tracking location preference data among anesthesia professionals first began at this hospital system in **2017**. Observed deterioration in the average rankings over time at several hospital locations since **2017** has led to identification of several addressable concerns, which has since prompted steady improvements in both perception of these hospitals as well as an increase in their average preference rankings. Therefore, dynamic location preference tracking could facilitate identification of quality improvement opportunities in a hospital system.

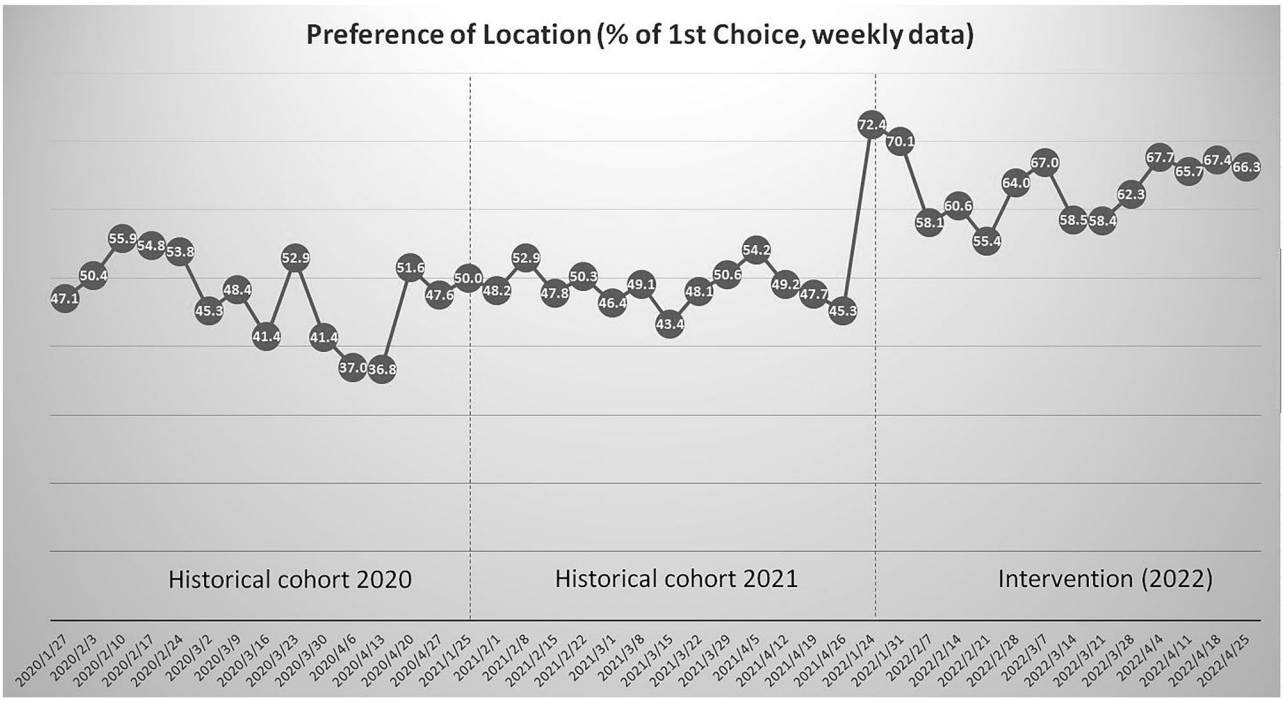

Fig. 4 Percentage of 1st Choice of Location Selection by Historical and Intervention Cohorts of Same Period of Time

Past studies have used electronic decision support to optimize work schedules, surgical team composition, and clinical assignments [4, 5, 10]. A prospective observational study utilized an electronic decision support tool to enhance OR case preferences among 101 anesthesia residents [4]. A case study of a New Jersey emergency department implemented an information systems decision support tool that used past patient census electronic data patterns to provide improvements in nursing scheduling practices [5]. Lastly, an electronic decision support tool considered historical specialized surgical team performance coupled with patient characteristics with the goal of optimizing orthopedic surgery team selection by making suggestions to schedulers [10].

Table 2 Interrupted Time Series Poisson Regression

Parameter	β	SE	IRR	p value
Between Two Historical Cohorts 2020–2021				
Slope for cohort 2020	−0.0158	0.0098	0.9843	0.1061
Slope for cohort 2021	−0.0025	0.0069	0.9975	0.7143
Level change	0.0139	0.0338	1.0140	0.6806
Slope change	0.0133	0.0120	1.0134	0.2661
Between Historical Cohort 2020 and Intervention				
Slope before intervention	−0.0158	0.0098	0.9843	0.1061
Slope after intervention	0.0001	0.0062	1.0001	0.9938
Level change	0.2820	0.0438	1.3258	< 0.0001
Slope change	0.0159	0.0116	1.0160	0.1711
Between Historical Cohort 2021 and Intervention				
Slope before intervention	−0.0025	0.0069	0.9975	0.7143
Slope after intervention	0.0001	0.0062	1.0001	0.9938
Level change	0.2680	0.0250	1.3073	< 0.0001
Slope change	0.0026	0.0093	1.0026	0.7819

Previous studies have also found success in applying electronic decision support tools to determine fair end of shift relief among anesthesiologists. A pre-, post- implementation study involving anesthesia residents suggested that an electronic decision support tool could provide shift relief priority information to senior residents in charge of relief decision-making [6]. Post survey data suggested an improvement in shift relief times among the resident cohort [6]. Another study of attending anesthesiologists at an urban hospital successfully enhanced equitable relief decisions through the use of a developed electronic decision support tool that presented a dashboard to the relief manager containing information on previously worked hours [7]. However, none of these studies specifically use an electronic decision support tool to place anesthesia professionals in their desired geographic work location. The methods outlined in this study offer an authentic means by which to improve scheduling preferences among anesthesia professionals through application of an electronic decision support tool.

The system was, by design, only making recommendations. The final decision for provider locations was left up to the AICs. Specific requests, required skill sets, required shift duration at specific locations all represent examples of where the AIC might not choose to follow the decision support

tool recommendations. Still, during the post-implementation period 91 changes were accepted by the AICs, consisting of 82 2-way trades, 8 3-way trades, and 1 4-way trade, resulting in a total of 192 improved shifts. The AICs shared their positive impression of the decision support tool with the Anesthesiology Vice Chair of Operations during regular scheduled operations meetings, as it was able to reduce the complexity of accommodating many location preferences when compared with the pre-implementation protocol.

While decision support tools have been implemented in other areas of healthcare management for quality improvement and optimization, this study is to our knowledge the first that attempted to more frequently accommodate a specific group of anesthesia professionals based on work location preference in a multi-hospital and surgical center system. As anesthesia groups continue to grow in size and in managing an increase in the number of anesthesia locations, a decision support tool could assist in optimizing provider schedules that could be superior to reliance solely on individual anesthesia schedulers. Similarly, electronic decision support tools could further aid in optimizing clinical assignments among all trainees so that they are able to meet or exceed their clinical requirements.

The present study has several limitations. First, the data was collected retrospectively during relatively short pre- and post-implementation periods of 14 weeks each. Therefore, it is not possible to discern whether the decision support tool will help to sustain the improvement in anesthesia professional location preference for longer durations of time. Furthermore, other unknown factors could have increased the location preference post-implementation such as the turnover of anesthesia professional workforce and the impact of COVID-19 on provider preferences. Second, the data collection occurred within one community based academic affiliate hospital system on the northside of Chicago and among one group of anesthesia professionals. Therefore, the results may not be generalizable to other hospital systems and healthcare professionals. Lastly, the study did not include a measure of provider satisfaction before or after the implementation of the decision support tool. In order to link schedule preference with overall satisfaction, further evaluation measures are required and are ongoing in a formal manner.

Despite the limitations of the study, the implementation of the developed decision support tool when integrated with anesthesia scheduling was found to increase the frequency with which anesthesia professionals were assigned to their number one location preference. The decision support tool offers a means to further accommodate healthcare providers based on geographic/site preference. Future studies should seek to prospectively and randomly assess how accommodation of location preference improves satisfaction and may reduce burnout among a broad-based group of healthcare providers.

Conclusion

Multiple studies suggest the potential benefits of decision support tool implementation in a multitude of healthcare settings. Despite the growing amount of literature on this topic, there is a lack of studies investigating decision support tool application in workplace location preference. As a first step, it was important to analyze the potential efficacy of implementing an electronic decision support tool among a focused group of anesthesia professionals to determine whether a higher frequency of 1st choice workplace selections could be achieved with this approach. Given the significant improvement in 1st choice selection of workplace among anesthesia professionals, future studies will be designed to broaden the scope of the program to a larger cohort of anesthesia professionals and analysis will take place over a longer period of time. Lastly, further studies should investigate the role of an electronic decision support tool in enhancing provider satisfaction and overall clinical experience.

Authors' contributions Mark Deshur had a significant role in the conception and design of the study, acquisition, analysis, and interpretation of the data, drafting and revising the current manuscript and final approval of the version submitted. Noah Ben-Isvy had a significant role in the conception and design of the study, acquisition, analysis, and interpretation of the data, drafting and revising the current manuscript and final approval of the version submitted. Chi Wang had a significant role in the conception and design of the study, acquisition, analysis, and interpretation of the data, drafting and revising the current manuscript and final approval of the version submitted. He specifically helped to prepare all statistical analysis and associated figures and tables. Mohammed Minhaj had a significant role in the conception and design of the study, acquisition, analysis, and interpretation of the data, drafting and revising the current manuscript and final approval of the version submitted. Steven Greenberg had a significant role in the conception and design of the study, acquisition, analysis, and interpretation of the data, drafting and revising the current manuscript and final approval of the version submitted.

Funding All funding was provided by the Department of Anesthesiology at NorthShore University HealthSystem.

Data availability Not applicable.

Declarations

Ethical approval and consent to participate Ethical approval and consent was waived by NorthShore University HealthSystem IRB as the article was deemed a quality improvement study that did not require it.

Human and animal ethics Not applicable.

Consent for publication Consent was waived by IRB as this was deemed a quality improvement study not requiring consent.

Competing interests Mark Deshur serves as a consultant to UKG. The homegrown scheduling system used at NorthShore University HealthSystem and the functionality studied in this publication are not related to any UKG product or his consulting.

Noah Ben-Isvy has no conflicts of interest.
Chi Wang has no conflicts of interest
Mohammed Minhaj has no conflicts of interest
Steven Greenberg has received a grant from the APSF to investigate the benefit of audio-visual decision support tools. In addition, he received a collaborative grant with the Department of Surgery at NorthShore University HealthSystem to investigate bioenvironmental contamination as it relates to performing three tracheostomy techniques.

References

1. Friedberg MW, Chen PG, Van Busum KR, Aunon F, Pham C, Caloyeras J, Mattke S, Pitchforth E, Quigley DD, Brook RH, Crosson FJ, Tutty M. Factors Affecting Physician Professional Satisfaction and Their Implications for Patient Care, Health Systems, and Health Policy. Rand Health Q. 2014;3(4):1.
2. Rizany I, Hariyati RTS, Afifah E. The Impact of Nurse Scheduling Management on Nurses' Job Satisfaction in Army Hospital: A Cross-Sectional Research. *SAGE Open*. 2019. https://doi.org/10.1177/2158244019856189.
3. Green, S., Markaki, A., Baird, J., Murray, P. and Edwards, R. (2020), Addressing Healthcare Professional Burnout: A Quality Improvement Intervention. Worldviews on Evidence-Based Nursing, 17: 213-220. https://doi.org/10.1111/wvn.12450.
4. Kim, P.Y., Wanderer, J.P., Allbritton, D.W. *et al.* Anesthesia Residents Preferentially Request Operating Room Case Assignments with Complex Cases. *J Med Syst* **41,** 64 (2017). https://doi.org/10.1007/s10916-017-0718-3
5. Otegbeye M, Scriber R, Ducoin D, Glasofer A. Designing a data-driven decision support tool for nurse scheduling in the emergency department: a case study of a southern New Jersey emergency department. J Emerg Nurs. 2015;41(1):30-5. https://doi.org/10.1016/j.jen.2014.07.003.
6. Bhutiani M, Jablonski PM, Ehrenfeld JM, McEvoy MD, Fowler LC, Wanderer JP. Decision Support Tool Improves Real and Perceived Anesthesiology Resident Relief Equity. Anesth Analg. 2018 Aug;127(2):513-519. https://doi.org/10.1213/ANE.0000000000003479.
7. Wax DB, McCormick PJ. A Real-Time Decision Support System for Anesthesiologist End- of-Shift Relief. Anesth Analg. 2017 Feb;124(2):599-602. https://doi.org/10.1213/ANE.0000000000001515.
8. Bernal JL, Cummins S, Gasparrini A. Interrupted time series regression for the evaluation of public health interventions: a tutorial. Int J Epidemiol. 2017 Feb 1;46(1):348-355. https://doi.org/10.1093/ije/dyw098. Erratum in: Int J Epidemiol. 2020 Aug 1;49(4):1414.
9. Godfrey LG: Misspecification tests and their uses in econometrics. J Stat Plan Inference 1996; 49:241–260. https://doi.org/10.1016/0378-3758(95)00039-9.
10. Ashkan Ebadi, Patrick J. Tighe, Lei Zhang, Parisa Rashidi, DisTeam: A decision support tool for surgical team selection. Artif. Intell. Med. 76, 16–26 (2017). https://doi.org/10.1016/j.artmed.2017.02.002.