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Appendix A. Supplementary data

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State of the anaesthesia workforce in the United States: trends and geographic variation in nurse anaesthetist to physician anaesthesiologist ratios

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Editor—Growing demand for anaesthesia services has resulted in a push towards more nurse-led (*vs* physician-led) care. Increases in certified registered nurse anaesthetist (CRNA) employment have been facilitated by various regulations, and 41 US states currently do not require physician-anaesthesiologist supervision of CRNAs. The Centers for Medicare and Medicaid Services allows state governors to opt out of the 'federal supervision' reimbursement requirement of physician supervision of non-physician anaesthesia providers, and 18 states have elected to do so.[1] In the absence of detailed data on the anaesthesia workforce in the USA, we sought to identify state-specific patterns in anaesthesiologist and CRNA employment.

We utilised state-level data from the US Bureau of Labor Statistics (BLS) Occupational Employment Statistics to evaluate patterns in anaesthesiologist and CRNA employment in 2012 compared with 2019. If data were not available for 2012 or 2019, the next available year was used. State-specific numbers of anaesthesiology residents were obtained from the Accreditation Council for Graduate Medical Education and added to anaesthesiologist employment data. We mapped changes in CRNA to anaesthesiologist ratios in all 50 states and Washington, DC between 2012 and 2019. The 'usmap' package in RStudio version 1.1.16 was used (R version 3.5.1; R Foundation for Statistical Computing, Vienna, Austria).

In 2019, there were 30 442 anaesthesiologists and 43 690 CRNAs employed across the USA compared with 30 774 anaesthesiologists and 34 170 CRNAs in 2012. CRNAs were more common in Southern and Midwestern states. From 2012 to 2019, increases in the CRNA to anaesthesiologist ratio were mostly seen in the Southeast and Midwest with the largest increase observed in Minnesota (from 0.93 to 4.80), an opt-out state. The largest increase in a non-opt-out state was observed in Mississippi (from 1.76 to 5.42; Fig. 1).

While anaesthesiologist employment has remained stable over the past 8 yr, CRNA employment increased by 25%. This has resulted in an increase in the CRNA to anaesthesiologist ratio in Southeastern and Midwestern states, not restricted to states that have opted out of federal physician supervision

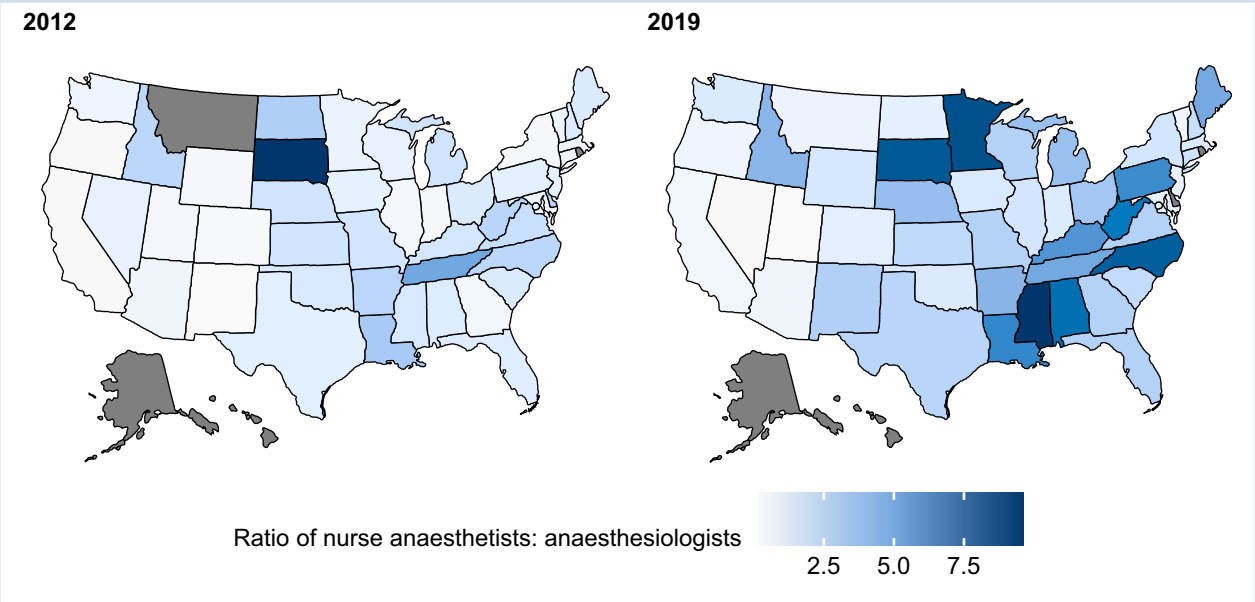

Fig 1. Heatmap of the USA representing state-specific nurse anaesthetist to anaesthesiologist ratios in 2012 compared with 2019.

requirements. To the contrary, growth was more pronounced in states that have not opted out.

These findings suggest a complex interplay between demands for anaesthesia care (and limited supply) in the context of various state and federal regulations. The rapid transition to CRNA-dominated care models may result in significant cost savings,[2] and analyses show that patients in opt-out states have not experienced changes in access to surgery.[3] However, it is not clear whether equivalent clinical outcomes can be expected. Studies comparing the quality of care between anaesthesiologists and CRNAs are not always independent,[4] have been generally assessed as 'low quality' and have been largely inconclusive.[5,6] Moreover, extreme outcomes such as mortality may not be adequate to determine quality and more common, but serious, complications, and discrepancies in resource utilisation related to care by practice model are needed.

Trends in anaesthesia care provided by CRNAs *vs* anaesthesiologists should be monitored, especially given current challenges in meeting increased demand. Differences in quality of care may be expected in more invasive surgeries or circumstances requiring critical care as is the context of the most recent expansion of CRNA privileges. The US Department of Veterans Affairs granted CRNAs the ability to practice without physician supervision as a response to the coronavirus disease 2019 pandemic.[7] This is a concerning policy shift since patients receiving care at these facilities are a particularly vulnerable population and many would likely benefit from optimal care team models.

This shift in the anaesthesia workforce and the potential impact on patient outcomes may be of interest to those outside of the USA looking to expand the role of non-physician anaesthesia providers to meet demand. In most European countries, anaesthesia care is physician-focused and non-physician anaesthesia providers are not permitted to practice independently.[8] Lessons from how this transition has affected the quality of anaesthesia care in the USA could prove beneficial in the decision-making process and potential implementation of this transition.

A limitation of these data is that we are unable to determine if CRNAs are practicing independently or being supervised by physicians. However, given that most states have seen dramatic increases in CRNA employment, it is likely that an increasing number are practicing without anaesthesiologist supervision, but further study is needed to validate this. Additionally, this data source may underestimate the true number of anaesthesiologists and CRNAs, although we do not expect any underestimation to be state-specific or time-dependent. Estimates of the physician and CRNA workforce vary widely across available data sources; we elected to use BLS data because of its role in policy making. To evaluate the robustness of our findings, we replicated this analysis with Center for Medicare and Medicaid Services (CMS) Physician Compare data files from 2014 and 2019. Despite differences in overall employment estimates, in all but three instances (Washington DC, Minnesota, and Montana) when we observed an increase in the CRNA to anaesthesiologist ratio in our data, an increase was also observed in the CMS data.

We observed substantial growth in CRNA employment across the USA while anaesthesiologist employment remained stable. This may reflect a cost- and access-based trend to provide CRNA-based anaesthesia care that is not sufficiently supported by quality data. Further study is necessary to quantify the impact of this transition on patient outcomes.

Authors' contributions

Helped in study design/planning: all authors
Interpretation of results: all authors
Data analysis: LAW
Manuscript preparation: LAW, JP, SGM
Manuscript review: all authors

Declarations of interest

SGM is a director on the boards of the American Society of Regional Anesthesia and Pain Medicine (ASRA) and the Society of Anesthesia and Sleep Medicine (SASM). He is a one-time consultant for Sandoz Inc. and Teikoku, and is currently on the medical advisory board of HATH. He has a pending US Patent application for a Multicatheter Infusion System (US-2017-0361063). He is owner of SGM Consulting, LLC and co-owner of FC Monmouth, LLC. None of the above relations influenced the conduct of the present study. All other authors declare that they have no conflicts of interest.

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Self-citation policies in anaesthesiology journals

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Editor—Compulsory self-citation and artificial self-promotion represent poor publishing practice.[1,2] Self-citations may be divided in author and journal self-citations (A-SC and J-SC, respectively). Although these are not related to each other, both should be considered during the review process.

The most common approach to define A-SC is counting as self-citation each time the article is cited by one of its co-authors. It has been estimated that each A-SC generates 3.65 additional citations over 10 yr.[3] Although some self-citations are certainly inevitable, inappropriate A-SC and 'citation farms' (clusters of authors citing themselves) create spurious citation metrics. As these metrics are taken into account for examinations, grants etc., this practice cannot be considered academically honest.

Excessive J-SC is another practice (unrelated to A-SC) resulting from inappropriate editorial requests to quote articles previously published in their journal in order to increase their impact factor (IF).[4] The J-SC is reported as:where the numerator represents the *delta* IF (contribution of self-citations to IF).

$$\text{JSC rate} = \frac{\text{IF} - \text{IF without self citations}}{\text{IF}}$$

Among proposed solutions to restrict self-citation practice is implementation of related policies. We conducted an observational investigation to describe the presence of policies for limiting A-SC and overall J-SC among anaesthesiology journals.