

# BMJ Open Quality Physicians' clinical experience and its association with healthcare quality: a systematised review

Soffien Chadli Ajmi ,<sup>1,2</sup> Karina Aase<sup>2,3</sup>

**To cite:** Ajmi SC, Aase K. Physicians' clinical experience and its association with healthcare quality: a systematised review. *BMJ Open Quality* 2021;**10**:e001545. doi:10.1136/bmjopen-2021-001545

► Additional supplemental material is published online only. To view, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2021-001545>).

Received 2 May 2021  
Accepted 22 October 2021



© Author(s) (or their employer(s)) 2021. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

<sup>1</sup>Department of Neurology, Stavanger University Hospital, Stavanger, Norway

<sup>2</sup>Faculty of Health Sciences, University of Stavanger, Stavanger, Norway

<sup>3</sup>SHARE Centre for Resilience in Healthcare, Faculty of Health Sciences, University of Stavanger, Stavanger, Norway

**Correspondence to**  
Dr Soffien Chadli Ajmi;  
soffiena@yahoo.com

## ABSTRACT

**Background and purpose** There is conflicting evidence regarding whether physicians' clinical experience affects healthcare quality. Knowing whether an association exists and which dimensions of quality might be affected can help healthcare services close quality gaps by tailoring improvement initiatives according to physicians' clinical experience. Here, we present a systematised review that aims to assess the potential association between physicians' clinical experience and different dimensions of healthcare quality.

**Methods** We conducted a systematised literature review, including the databases MEDLINE, Embase, PsycINFO and PubMed. The search strategy involved combining predefined terms that describe physicians' clinical experience with terms that describe different dimensions of healthcare quality (ie, safety, clinical effectiveness, patient-centredness, timeliness, efficiency and equity). We included relevant, original research published from June 2004 to November 2020.

**Results** Fifty-two studies reporting 63 evaluations of the association between physicians' clinical experience and healthcare quality were included in the final analysis. Overall, 27 (43%) evaluations found a positive or partially positive association between physicians' clinical experience and healthcare quality; 22 (35%) found no association; and 14 (22%) evaluations reported a negative or partially negative association. We found a proportional association between physicians' clinical experience and quality regarding outcome measures that reflect safety, particularly in the surgical fields. For other dimensions of quality, no firm evidence was found.

**Conclusion** We found no clear evidence of an association between measures of physicians' clinical experience and overall healthcare quality. For outcome measures related to safety, we found that physicians' clinical experience was proportional with safer care, particularly in surgical fields. Our findings support efforts to secure adequate training and supervision for early-career physicians regarding safety outcomes. Further research is needed to reveal the potential subgroups in which gaps in quality due to physicians' clinical experience might exist.

## INTRODUCTION

Healthcare quality can be defined as 'the extent to which healthcare services provided to individuals and patient populations improve desired health outcomes'.<sup>1</sup> The Institute of Medicine provides an examination of the divide between

good healthcare and provided healthcare.<sup>2</sup> To describe, measure and thus improve healthcare quality, the Institute of Medicine proposed six dimensions: safety, effectiveness, timeliness, efficiency, patient-centredness and equity. More recently, WHO added 'integrated care' as the seventh dimension in their definition of quality in healthcare.<sup>3</sup> Improvement of these dimensions is required to eventually 'cross the quality chasm'.

Quality gaps exist at all levels of the healthcare system, including at the level of the treating physician. Specifically, physicians' clinical experience and its effects on variations in healthcare quality remain disputed. A broad range of findings are reported, with reported associations varying between different medical fields.<sup>4-8</sup> Empirically, a physician's clinical experience is typically measured by his or her age or years in clinical practice.<sup>9</sup> Knowing whether a physician's clinical experience can affect healthcare quality and which dimensions of quality might be affected can help healthcare services close potential quality gaps by tailoring improvement initiatives.

A comprehensive, systematic review within the field was undertaken in 2005 by Choudhry and colleagues; it showed an overall inverse relationship between physicians' clinical experience and quality.<sup>10</sup> This review is now over 15 years old; thus, an updated review could provide valuable knowledge. We, therefore, present a systematised review of recent articles that study the association between physicians' clinical experience and healthcare quality. Our primary aim was to determine whether there is evidence of an association between physicians' clinical experience and healthcare quality, and whether an association is attributable to the Institute of Medicine's specific dimensions of healthcare quality. Outcome measures related to integrated care were not included as these typically measure 'coproductive partnerships', and thus relating these to characteristics at the level of the individual treating physician would be difficult.<sup>11</sup>

**Table 1** Search strategy

| Description   | Search terms           | Additional search terms |                     |                      |
|---|------------------------|-------------------------|---------------------|----------------------|
| Terms that describe physicians' clinical experience | Physician experience   | Physician age           | Physician seniority | Clinician experience |
| Terms that describe dimensions of quality           | Safety                 | Patient safety          | Adverse events      | Errors               |
|   | Clinical effectiveness | Patient outcome         | Outcomes            | Mortality            |
|   | Patient-centredness    | Patient experience      |                     |                      |
|   | Timeliness             | Delay                   | Waiting time        | Treatment time       |
|   | Efficiency             | Waste                   | Cost-effective      |                      |
|   | Equity                 | Fairness                | Equality            |                      |

## METHODS

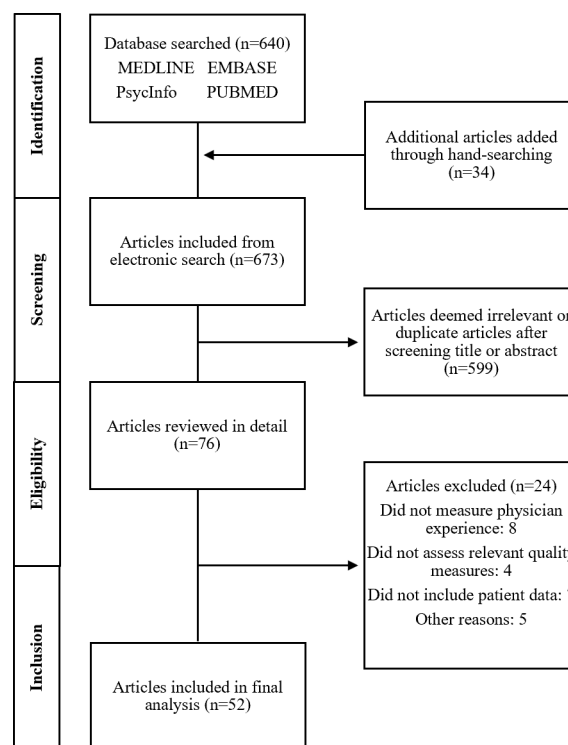
We conducted a systematised review (according to Grant and Booth<sup>12</sup>) including the databases MEDLINE, Embase, PsycINFO and PubMed. The search strategy involved combining terms that describe physicians' clinical experience with terms that describe different dimensions of healthcare quality. The terms for the dimensions of healthcare quality were derived from the Institute of Medicine.<sup>2</sup> A test search revealed several slightly different concepts that cover both physicians' clinical experience and the dimensions of healthcare quality. Specifically, by using the term 'physician experience', we found several potentially relevant articles. Hand searching the list of references and other related articles, we found that several potentially relevant articles could only be retrieved through using the terms 'physician age', 'physician seniority' or 'clinician experience'. We also found that some of the articles describing physician experience used caseload as a proxy. In this review, the term physician experience therefore describes years in practice, age or caseload. Each term that describes physicians' clinical experience was combined with all the terms that describe dimensions of quality by using the operator 'AND'. The search terms used in the final search are listed in table 1.

Titles and/or abstracts were screened for inclusion. After retrieving potentially relevant articles, we hand searched a list of articles listed in PubMed as 'related to' or 'citing' the previously published guiding review by Choudhry and colleagues on the subject.<sup>10</sup> The review by Choudhry and colleagues included relevant studies before June 2004; thus, we included articles published from June 2004 to November 2020. Only original studies that assess the association between process or outcome measures that reflect one or several dimensions of healthcare quality and a measure of physicians' clinical experience were included. For studies that assess several outcome or process measures, we included only relevant measures. The selection process is outlined in figure 1.

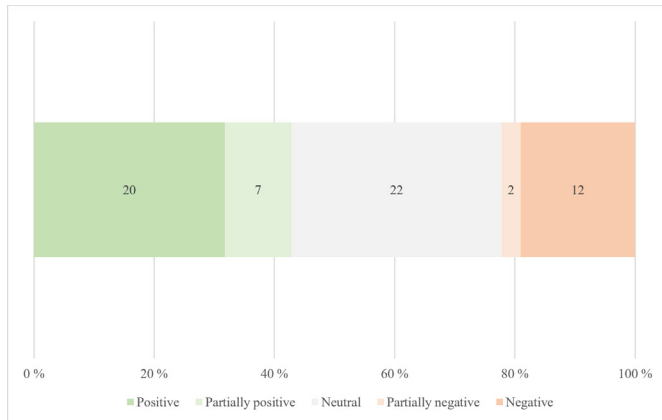
We reviewed each dimension of healthcare quality separately. Relevant outcomes from each article were thus categorised according to dimension. Descriptions of each quality dimension included in the Institute of Medicine report were used for classification.<sup>2</sup> For example, measures of adverse events were classified as safety adherence to

guidelines for treatments were classified as clinical effectiveness and the time required until treatment or diagnosis was classified as timeliness. Some outcome measures were not easily classified into specific quality dimensions. For example, readmission is a complex quality indicator that might reflect several dimensions of quality.<sup>13</sup> Complex outcome measures were therefore classified to the best of our abilities and, in the case of readmissions, as a measure of safety.

For each included study, we reported the following parameters: study design, medical field, sample size, key results and the nature of the association. The nature of the association was classified as either positive (proportional relationship between measures of physicians' clinical experience and healthcare quality), neutral (no association) or negative (inverse relationship between measures of physicians' clinical experience and healthcare quality).



**Figure 1** Selection process for the articles included in this study.



**Figure 2** Overall frequency and the nature of associations between physicians' clinical experience and healthcare quality. A total of 63 associations from 52 articles were included; positive: a proportional relationship between healthcare quality and physicians' clinical experience; partial: some but not all outcomes within an evaluation pointed in one direction; negative: inverse relationship between healthcare quality and physicians' clinical experience.

Whenever some but not all outcome measures from a single study were associated with measures of physicians' clinical experience, the evaluation was classified as either partially positive or partially negative. We did not perform a formal meta-analysis of quantitative results, assess the validity of our search strategy or formally assess the quality of the included studies.

## RESULTS

Fifty-two studies were included in the review sample. Thirty-four of the included studies originated from the USA. Fifty were observational; of these, 36 were retrospective cohort studies. With regard to medical fields, 12 studies assessed different surgical fields; 3 assessed psychiatrists; and 6 assessed general practitioners; the remaining 31 studies assessed disciplines within internal medicine or a mixed group of physicians. Details of the study design and medical fields are presented in online supplemental table 1.

The 52 included studies reported 63 evaluations (groups of, or single, relevant outcomes) of the association between physicians' clinical experience and healthcare quality. Twenty-seven (43%) of the 63 included evaluations reported a positive or partially positive association between physicians' clinical experience and healthcare quality; 22 (35%) found no association; and 14 (22%) evaluations reported a negative or partially negative association (figure 2).

### Safety

We included 11 studies that assessed outcome measures related to safety.<sup>6 14–23</sup> Of these, six (54%) found a positive or partially positive association with physicians' clinical experience, and five (46%) were neutral (see online supplemental table 1 and figure 3). Four out of



**Figure 3** Frequency of associations grouped into six healthcare quality dimensions. A total of 63 associations from 52 articles were included; positive: proportional relationship between quality and physicians' clinical experience; partial: some but not all outcomes within an evaluation pointed in one direction; negative: inverse relationship between quality and physicians' clinical experience.

the six (67%) studies that found a positive association included only surgical patients. The study by Epstein and colleagues was the most comprehensive of the included evaluations of safety; they analysed the association between various complications after birth deliveries (vaginal and caesarean) and physicians' years in practice.<sup>18</sup> A 0.21% reduction in complication rates per year in the first decade of training (95% CI –0.23 to –0.19) was found, a 0.11% reduction in the second decade and a 0.05% reduction in the third decade. The association between years of training and reduced complication rates was thus positive and most pronounced during the first decade of training.

Another study by Berk and colleagues evaluated 829 emergency room cases that involved an adverse outcome (eg, death, concerns from staff or family, readmission, etc).<sup>16</sup> By peer review, cases where low healthcare quality could be attributed to a cognitive error by the treating physician were identified. The authors found that emergency physicians with 1.5 years of experience or more were significantly less likely to make an error (Relative Risk=0.66, 95% CI 0.48 to 0.91). This is the only included study that performed a comprehensive review of potential low-quality healthcare cases before attributing them to physician errors.

Five other studies did not find an association.<sup>14 19 21–23</sup> This included the only interventional study with a quasi-experimental design by Southern and colleagues.<sup>21</sup> In this study, 30-day readmission rates and years in practice (in 5-year increments) were studied; no significant association was found across different age groups. None of the included studies showed a negative association.

### Clinical effectiveness

We included 26 studies that assessed outcome measures related to clinical effectiveness.<sup>6–8 14 21 24–44</sup> Of these, 10 (38%) found a positive or partially positive association with physicians' clinical experience; 10 (38%) found no

association; and 6 (24%) were negative or partially negative (see online supplemental table 1 and figure 3). The study by Satkunasivam and colleagues was one of the largest studies, including 1 159 676 patients who had been treated by 3314 surgeons.<sup>6</sup> They found a reduced risk of 30-day mortality for each 10-year increase in surgeon age and for the surgeons with the highest case volumes.

Several other studies assessed both case volume, age, or years of training as a measure of physicians' clinical experience, with conflicting results. Chai and colleagues analysed the association between thoracic surgeons' age and mortality for 3766 patients and found lower mortality rates for surgeons >45 years old regardless of caseloads.<sup>28</sup> Khatana and colleagues studied 356 interventional cardiologists and 1 45 247 cases with regard to deaths per 100 cases.<sup>7</sup> They found a higher caseload, but not the number of years since medical school training, to be associated with reduced mortality.

A large study by Conway and colleagues included 36 271 patients with 66 933 emergency room admissions and analysed the association between the emergency physician's years of experience and mortality.<sup>29</sup> The study found a reduced risk of 30-day mortality for physicians with more than 20 years of experience, only for high-risk patients. This is the only included study that stratified outcomes by a patient's risk profile.

### Patient-centredness

We included five studies that assessed outcome measures related to patient-centredness.<sup>5 33 45–47</sup> Of these, two (40%) found a positive or partially positive association with physicians' clinical experience, and three (60%) found no association (see online supplemental table 1 and figure 3). The study by Fathy and colleagues evaluated the effect of physicians' age on patient satisfaction; this was one of the largest studies, including 1342 ophthalmologists.<sup>45</sup> They found that the time to the first unsolicited complaint was the highest (ie, better quality) with ophthalmologists older than 70 years. The association with age assumed an almost linear pattern for 10-year increments from the age of 30. The nature of the complaints (eg, communication, care, treatment, etc) was similar across all age groups.

With regard to technical procedures, Seely and colleagues included physicians performing stereotactic biopsies and studied the association between patient-satisfaction scores (with regard to pain and bruising from the procedure) and the treating physicians' years in practice.<sup>47</sup> For stereotactic vacuum-assisted biopsies, they found that patients of more experienced physicians reported significantly less pain and bruising ( $p=0.0013$ ).

### Timeliness

We included five studies that assessed outcome measures related to timeliness.<sup>4 14 32 40 41</sup> Of these, two (40%) found a positive association with physicians' clinical experience; one (20%) was neutral; and two (40%) were negative (see online supplemental table 1 and figure 3). The

studies that found a positive association had a prospective design, but the advantages in the design might have been offset by the larger number of patients included in the two retrospective studies that found a negative association.<sup>4 14 32 40</sup> Both the study by Harvey and colleagues and the study by Li and colleagues included emergency physicians and analysed the association between waiting times in the emergency room and physicians' clinical experience.<sup>32 40</sup> Harvey and colleagues concluded with shorter waiting times for the patients of more experienced physicians, while Li *et al* had the opposite conclusion.

The only study that assessed timeliness according to differences in diagnostic accuracy in a technical procedure was performed by Mehrotra and colleagues.<sup>4</sup> They included 104 618 patients and assessed adenoma detection rates in gastroscopy. They found a mean detection rate that was 6% higher in physicians who had less than 9 years since their residency completion ( $p=0.004$ ) compared with physicians who had 27–51 years of practice.

### Efficiency

We included 14 studies that assessed outcome measures related to efficiency.<sup>21 24 29 40 48–57</sup> Of these, six (43%) found a positive or partially positive association with physicians' clinical experience; two (14%) found no association; and six (43%) were negative (see online supplemental table 1 and figure 3). None of the included studies assessed surgical patients; otherwise, the included studies represented a broad range of settings.

Schwartz and colleagues performed one of the largest studies, including 3 159 834 patients and 41 773 generalist physicians.<sup>55</sup> They defined 17 primary care-associated, low-value services (minimum clinical benefit) and counted the annual rates of these services per 100 patients per year. After including age as one of several physician characteristics, they found a significant increase in low-value services per 10-year increase in age, thus concluding with a negative association between age and healthcare quality. This is the only included study that adjusted for within-region and within-organisation variations.

Two of the included studies assessed costs per case as a measure of efficiency, and both showed a positive association. Cournane and colleagues included 19 295 emergency department patients and analysed the association between years of experience and costs per case.<sup>48</sup> Five-year increments of increased experience above 15 years had a significantly reduced OR for costs below the median. Mehrotra and colleagues included 2 861 093 claims attributed to 12 724 physicians and compared the expected costs for the condition in question with the cost apparent from the claim.<sup>52</sup> Compared with physicians with more than 40 years of experience, physicians with fewer years of experience had higher cost profile scores. Both studies, therefore, concluded that more experienced physicians had beneficial cost profiles.

## Equity

Only one study with outcomes related to equity was included. The study by Essien and colleagues included 143 274 patients of both resident and staff primary care physicians.<sup>58</sup> They collected details regarding patient's ethnicity, insurance status, poverty and education, in addition to quality outcomes such as guideline-concordant disease management, screening, resource use and patient-reported health experience. They found that resident physicians had a higher proportion of typically underserved populations than staff physicians and that when controlling for patient factors, residents had lower scores for all quality-outcome measures, except for patient experience. The authors found that residents and staff physicians serve significantly different patient groups. The lower healthcare quality provided by residents compared with staff physicians thus represented an equity problem with typically underserved populations receiving lower-quality care.

## Other

The study by Reid and colleagues could not be categorised within a specific quality dimension, as their outcome measure was a composite performance score of 124 different quality measures assessing several dimensions of quality.<sup>59</sup> The study was comprehensive, including 1.13 million patients and 10 408 physicians from a broad range of settings. They included several physician characteristics, including age, but did not find an association between age and healthcare quality.

## DISCUSSION

In this systematised literature review of 52 studies, we found that the most frequently reported association was a proportional association between physicians' clinical experience and overall quality of care (43%). However, a relatively large proportion of evaluations found no association (35%) or even an inverse relationship between a physician's clinical experience and quality (22%). Regarding specific dimensions of healthcare quality, in our sample, 26 studies that assessed the associations between a physicians' clinical experience and measures of clinical effectiveness were included. There was a substantial dispersion regarding the nature of the associations in these studies, with similar proportions of studies reporting a proportional, neutral and inverse association. A similar pattern emerged for the 14 studies that assessed measures of efficiency. For the 11 studies that assessed measures of safety, most reported a proportional association between physicians' clinical experience and measures of safety (54%), with no inverse associations found. This was primarily driven by studies that assessed surgeons. For patient-centredness, two of the included studies were positive (40%), with no negative association, but only five studies were included overall, and most of these (60%) found no association. Only one included study assessed equity and found a positive association.

Due to the heterogeneity of the included studies and the relatively small differences in proportions, we cannot conclude with evidence of an association between physicians' clinical experience and overall healthcare quality. For different dimensions of quality, our results indicate that, for outcome measures that reflect safety, there is a proportional association between physicians' clinical experience and quality. For the other dimensions of quality, no firm evidence of association was found.

Theoretically, there are plausible explanations for both a proportional and an inverse relationship between physicians' clinical experience and healthcare quality. More experienced physicians, through the accumulation of tacit knowledge and skills, might provide higher-quality care than their less experienced peers. However, an experienced physician might also provide poorer quality due to a lower willingness to adopt new therapies, the ineffectiveness of continuing medical education programmes or even neurocognitive changes associated with advancing age.<sup>60</sup> An additional explanation for studies that report neutral or inverse associations is related to the definition of physicians' clinical experience. In most of the included studies, this was narrowly defined as either their years in practice or age, and, in a few studies, as case volume. Elstad and colleagues argue that what physicians gain over time is complex social, behavioural and intuitive wisdom, as well as the ability to compare present-day patients against similar past patients.<sup>9</sup> This acquired understanding of patient types might lead to better care that is not captured by common quality indicators. In some instances, deliberately disregarding guidelines due to an understanding of patient types can be warranted and lead to better quality. In most studies, this potential quality contribution is overlooked, and the lack of adherence to guidelines is prematurely reported as deficient care. This highlights some of the challenges with the narrow definitions or proxies for physician experience such as age or years in practice used in most included articles. Berk and colleagues' study was the only article in which potential low-quality cases underwent peer review before being classified as a physician's cognitive error.<sup>16</sup> Through peer review, the risk of overlooking increases in quality that are not captured by common quality indicators is reduced. They found a positive association between quality and a physician's experience, and thus might support the theory stated by Elstad and colleagues.

Our findings contrast those reported by Choudhry and colleagues in 2005, indicating an inverse relationship between physicians' clinical experience and healthcare quality.<sup>10</sup> There are possible explanations for this. First, Choudhry and colleagues argued that their results could be due to a 'cohort' effect. The cohort effect in this context means that an inverse relationship between physicians' clinical experience and quality could be due to the substantial changes that have occurred in medicine over the past decades (eg, adaptation of evidence-based medicine and quality assurance techniques). Reduced familiarity with this among the older physicians included



in their review might have led to lower quality. The cohort of older physicians included in the studies that formed the basis of the review by Choudhry and colleagues (from 1966 to 2004) is probably not included in our review; thus, this disparity in quality due to a potential cohort effect is expected to be absent or less pronounced in the current review. Second, the review by Choudhry and colleagues typically included articles that assessed knowledge and adherence to diagnosis or therapy through self-reported data, while only seven of the articles reported health outcomes. Most articles included in this current review reported health outcomes. Comparing the included studies that reported only health outcomes, we found that the difference between the two reviews is less pronounced.

Other more recent literature reviews within specific clinical specialties report findings similar to this review. Melfa and colleagues conducted a review of surgical fields and found that higher volume was associated with better quality. For the individual surgeon, the results were particularly evident regarding complications.<sup>61</sup> This result echoes our findings regarding the safety dimension. Another literature review by van der Leeuw and colleagues studied the effect of residency training and experience on patient outcomes and concluded that overall patient care appears safe and of equal quality when delivered by resident physicians compared with more experienced staff.<sup>62</sup> This supports our conclusion that there is no significant overall association between physicians' clinical experience and healthcare quality.

Our systematised review has several limitations. First, we included a heterogeneous group of studies that included assessments of technical and non-technical skills, early-career, and late-career, acute and elective treatments, each within a broad range of medical fields. Thus, there is a possibility that opposite effects in subgroups might have cancelled each other, masking potential associations. Second, regarding the dimensions of quality, some of the dimensions had too few studies to draw firm conclusions about associations. This is particularly the case for the equity dimension. A better search strategy might have helped include more studies. Third, our study focused on potential effects of individual physician characteristics on healthcare quality. Healthcare quality is dependant of a complex set of factors including individual factors, team factors and system factors to achieve successful outcomes. Considering the multitude of factors that might influence healthcare quality, variation attributable to characteristics of the treating physician constitutes only part of the overall variation. Fourth, the narrow definition of physician experience used in this review might have excluded articles using more sophisticated proxies for experience than age or years in practice. One could argue that including other proxies of experience, such as breadth (eg, working in a variety of different healthcare settings), would have resulted in the inclusion of articles reflecting a broader range of physician experience. Fifth, we might have introduced bias by including a large proportion of

articles that cite the review by Choudhry and colleagues.<sup>10</sup> If, for instance, studies that reported a negative association were more likely to cite this review as a confirmation of their findings, we would have overlooked the possibility of a larger effect towards positive associations. Given the large number of included studies, however, a significant bias is less likely, and it is difficult to predict its potential direction. Sixth, most of the included studies were retrospective cohort studies and thus had inherent weaknesses related to study design. Finally, regarding generalisability, almost all the included studies were from Organisation for Economic Co-operation and Development countries (the majority of these were from the USA). Thus, our findings might not be directly applicable to other settings.

Despite these limitations, our findings do suggest that an overall healthcare quality gap related to physicians' clinical experience is either non-existent, ambiguous or no longer relevant. This has implications for future research, as more specific studies are needed to determine the potential effects in subgroups, particularly regarding equity. Furthermore, our findings suggest that there is a possible quality gap regarding the safety dimension, as physicians' clinical experience is positively associated with safer care. This is particularly true for surgeons, and efforts to secure adequate training and supervision of novice surgeons are warranted. Finally, several of the included studies reported large variations at the physician level that could not be attributable to observable measures, such as age or years of experience.<sup>26 30 37 42 55 56 59</sup> Physician-level individual variation is thus an important cause of disparities in healthcare quality, and explaining this variation through measures other than age or years of experience will be important in eventually addressing quality gaps.

## CONCLUSION

We found no clear evidence of an association between measures of physicians' clinical experience and overall healthcare quality. For outcome measures related to safety, we found that physicians' clinical experience was proportional with safer care, particularly in surgical fields. For other quality dimensions, we found no firm evidence of an association. Further research is needed to reveal potential subgroups in which disparities in healthcare quality might exist.

**Twitter** Soffien Chadli Ajmi @SoffienA

**Contributors** SCA and KA conceived the research questions and search strategy and approved the final version. SCA performed the literature review, drafted the work and was responsible for the overall content as guarantor. KA did several critical revisions for important intellectual content.

**Funding** SCA is a research fellow funded by a Safer Healthcare Grant (University Research Fund). Otherwise, the authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

**Competing interests** None declared.

**Patient consent for publication** Not applicable.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data availability statement** There are no data in this work.

**Supplemental material** This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

**Open access** This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

#### ORCID iD

Soffien Chadli Ajmi <http://orcid.org/0000-0002-4751-5664>

## REFERENCES

- WHO. Quality of care. Available: <https://www.who.int/teams/maternal-newborn-child-adolescent-health-and-ageing/quality-of-care2020> [Accessed 12 Dec 2020].
- Institute of Medicine Committee on Quality of Health Care in A. Crossing the quality chasm: a new health system for the 21st century. Washington, D.C National Academy Press; 2001.
- World Health O, Organisation for Economic C-o, Development, International Bank for R, Development. Delivering quality health services: a global imperative for universal health coverage. Geneva World Health Organization; 2018.
- Mehrotra A, Morris M, Gourevitch RA, et al. Physician characteristics associated with higher adenoma detection rate. *Gastrointest Endosc* 2018;87:778–86.
- Nuyen BA, Altamirano J, Fassiotto M, et al. Effect of surgeon Sociodemographics on patient-reported satisfaction. *J Am Coll Surg* 2020;231:S138.
- Satkunasingam R, Klaassen Z, Ravi B, et al. Relation between surgeon age and postoperative outcomes: a population-based cohort study. *CMAJ* 2020;192:E385–92.
- Khatana SAM, Fiorilli PN, Nathan AS, et al. Association between 30-day mortality after percutaneous coronary intervention and education and certification variables for new York state interventional cardiologists. *Circ Cardiovasc Interv* 2018;11:e006094.
- Glassman JR, Hopkins DSP, Bundorf MK, et al. Association between HEDIS performance and primary care physician age, group affiliation, training, and participation in ACA exchanges. *J Gen Intern Med* 2020;35:1730–5.
- Elstad EA, Lutfey KE, Marceau LD, et al. What do physicians gain (and lose) with experience? Qualitative results from a cross-national study of diabetes. *Soc Sci Med* 2010;70:1728–36.
- Choudhry NK, Fletcher RH, Soumerai SB. Systematic review: the relationship between clinical experience and quality of health care. *Ann Intern Med* 2005;142:260–73.
- Goodwin N. Understanding integrated care. *Int J Integr Care* 2016;16.
- Grant MJ, Booth A. A typology of reviews: an analysis of 14 review types and associated methodologies. *Health Info Libr J* 2009;26:91–108.
- Fischer C, Lingsma HF, Marang-van de Mheen PJ, et al. Is the readmission rate a valid quality indicator? A review of the evidence. *PLoS One* 2014;9:e112282.
- Helsinki Stroke Thrombolysis Registry Group. Does time of day or physician experience affect outcome of acute ischemic stroke patients treated with thrombolysis? A study from Finland. *Int J Stroke* 2012;7:511–6.
- Atkinson MK, Schuster MA, Feng JY, et al. Adverse events and patient outcomes among hospitalized children Cared for by general pediatricians vs hospitalists. *JAMA Netw Open* 2018;1:e185658.
- Berk WA, Welch RD, Levy PD, et al. The effect of clinical experience on the error rate of emergency physicians. *Ann Emerg Med* 2008;52:497–501.
- Campbell RJ, El-Defrawy SR, Gill SS, et al. Association of cataract surgical outcomes with late surgeon career stages: a population-based cohort study. *JAMA Ophthalmol* 2019;137:58–64.
- Epstein AJ, Srinivas SK, Nicholson S, et al. Association between physicians' experience after training and maternal obstetrical outcomes: cohort study. *BMJ* 2013;346:f1596.
- McMahon P, Dididze M, Levi AD. Incidental durotomy after spinal surgery: a prospective study in an academic institution. *J Neurosurg Spine* 2012;17:30–6.
- Skolka M, Lehman E, Khalid M, et al. Physician characteristics correlate with Hospital readmission rates. *Medicine* 2020;99:e19363.
- Southern WN, Bellin EY, Arnsten JH. Longer lengths of stay and higher risk of mortality among inpatients of physicians with more years in practice. *Am J Med* 2011;124:868–74.
- Stevens H, Carlin AM, Ross R, et al. Effect of surgeon age on bariatric surgery outcomes. *Ann Surg* 2018;267:905–9.
- Theodoro D, Krauss M, Kollef M, et al. Risk factors for acute adverse events during ultrasound-guided central venous cannulation in the emergency department. *Acad Emerg Med* 2010;17:1055–61.
- Abe T, Moriya M, Ikeda K, et al. Psychiatrist characteristics related to patient outcome in Japan. *Psychiatr Q* 2012;83:221–39.
- Anderson BR, Wallace AS, Hill KD, et al. Association of surgeon age and experience with congenital heart surgery outcomes. *Circ Cardiovasc Qual Outcomes* 2017;10.
- Ashy N, Nguyen T-N, Denhaerynck K, et al. Hierarchical modeling of patient and physician determinants of blood pressure outcomes in hypertensive patients with and without diabetes: pooled analysis of six observational valsartan studies with 15,282 Evaluable patients. *Int J Chronic Dis* 2017;2017:9842450.
- Bjornsson HM, Marelsson S, Magnusson V, et al. Physician experience in addition to ACLS training does not significantly affect the outcome of prehospital cardiac arrest. *Eur J Emerg Med* 2011;18:64–7.
- Chai C-Y, Chen C-H, Lin H-W, et al. Association of increasing surgeon age with decreasing in-hospital mortality after coronary artery bypass graft surgery. *World J Surg* 2010;34:3–9.
- Conway R, Byrne DG, O'Riordan D, et al. Improved outcomes of high-risk emergency medical admissions cared for by experienced physicians. *QJM* 2015;108:119–25.
- Funkhouser E, Houston TK, Levine DA, et al. Physician and patient influences on provider performance:  $\beta$ -blockers in postmyocardial infarction management in the MI-Plus study. *Circ Cardiovasc Qual Outcomes* 2011;4:99–106.
- Goodwin JS, Salameh H, Zhou J, et al. Association of hospitalist years of experience with mortality in the hospitalized Medicare population. *JAMA Intern Med* 2018;178:196–203.
- Harvey M, Al Shaar M, Cave G, et al. Correlation of physician seniority with increased emergency department efficiency during a resident doctors' strike. *N Z Med J* 2008;121:59–68.
- Haubitz-Eschelbach A, Durmisi M, Haubitz S, et al. The glory of the age is the wisdom of grey hair: association of physician appearance with outcomes in hospitalised medical patients - an observational study. *Swiss Med Wkly* 2019;149:w20162.
- Hsu JC, Badhwar N, Lee BK, et al. Predictors of fluoroscopy time and procedural failure during biventricular device implantation. *Am J Cardiol* 2012;110:240–5.
- Huntington SF, Hoag JR, Wang R, et al. Physician experience and risk of rituximab discontinuation in older adults with non-Hodgkin's lymphoma. *J Natl Compr Canc Netw* 2019;17:1194–202.
- Jasuja GK, Bhasin S, Rose AJ, et al. Provider and site-level determinants of testosterone prescribing in the Veterans healthcare system. *J Clin Endocrinol Metab* 2017;102:3226–33.
- Kerlin MP, Epstein A, Kahn JM, et al. Physician-level variation in outcomes of mechanically ventilated patients. *Ann Am Thorac Soc* 2018;15:371–9.
- Lee H-C, Lin H-C. Are psychiatrist characteristics associated with postdischarge suicide of schizophrenia patients? *Schizophr Bull* 2009;35:760–5.
- Levie M, Chudnoff SG. A comparison of novice and experienced physicians performing hysteroscopic sterilization: an analysis of an FDA-mandated trial. *Fertil Steril* 2011;96:643–8.
- Li C-J, Syue Y-J, Tsai T-C, et al. The impact of emergency physician seniority on clinical efficiency, emergency department resource use, patient outcomes, and disposition accuracy. *Medicine* 2016;95:e2706.
- Lindenauer PK, Behal R, Murray CK, et al. Volume, quality of care, and outcome in pneumonia. *Ann Intern Med* 2006;144:262–9.
- McAlister FA, Youngson E, Bakal JA, et al. Physician experience and outcomes among patients admitted to general internal medicine teaching wards. *CMAJ* 2015;187:1041–8.
- Miller ES, Battarbee A, Moser A. Association between physician experience and obstetric outcomes after vacuum delivery. *Journal of Reproductive Medicine* 2018;63:131–6.



- 44 Slinin Y, Guo H, Li S, *et al.* Hemodialysis patient outcomes: provider characteristics. *Am J Nephrol* 2014;39:367–75.
- 45 Fathy CA, Pichert JW, Domenico H, *et al.* Association between ophthalmologist age and Unsolicited patient complaints. *JAMA Ophthalmol* 2018;136:61–7.
- 46 Obele CC, Duszak R, Hawkins CM, *et al.* What patients think about their interventional radiologists: assessment using a leading physician ratings website. *J Am Coll Radiol* 2017;14:609–14.
- 47 Seely JM, Hill F, Peddle S, *et al.* An evaluation of patient experience during percutaneous breast biopsy. *Eur Radiol* 2017;27:4804–11.
- 48 Courname S, Conway R, Creagh D, *et al.* Consultant duration of clinical practice as a cost determinant of an emergency medical admission. *Eur J Health Econ* 2015;16:561–7.
- 49 Davenport MS, Khalatbari S, Keshavarzi N, *et al.* Differences in outcomes associated with individual radiologists for emergency department patients with headache imaged with CT: a retrospective cohort study of 25,596 patients. *AJR Am J Roentgenol* 2020;214:1122–30.
- 50 Ellis SD, Nielsen ME, Carpenter WR, *et al.* Gonadotropin-Releasing hormone agonist overuse: urologists' response to reimbursement and characteristics associated with persistent overuse. *Prostate Cancer Prostatic Dis* 2015;18:173–81.
- 51 Howard DH, Hockenberry J. Physician age and the abandonment of episiotomy. *Health Serv Res* 2019;54:650–7.
- 52 Mehrotra A, Reid RO, Adams JL, *et al.* Physicians with the least experience have higher cost profiles than do physicians with the most experience. *Health Aff* 2012;31:2453–63.
- 53 Piovani D, Clavenna A, Cartabia M, *et al.* Assessing the quality of paediatric antibiotic prescribing by community paediatricians: a database analysis of prescribing in Lombardy. *BMJ Paediatr Open* 2017;1:e000169.
- 54 Rose-Felker K, Kelleman MS, Campbell RM, *et al.* Appropriate Use and Clinical Impact of Echocardiographic "Evaluation of Murmur" in Pediatric Patients. *Congenit Heart Dis* 2016;11:721–6.
- 55 Schwartz AL, Jena AB, Zaslavsky AM, *et al.* Analysis of physician variation in provision of low-value services. *JAMA Intern Med* 2019;179:16–25.
- 56 Tan A, Zhou J, Kuo Y-F, *et al.* Variation among primary care physicians in the use of imaging for older patients with acute low back pain. *J Gen Intern Med* 2016;31:156–63.
- 57 Tang VL, Shi Y, Fung K, *et al.* Clinician factors associated with prostate-specific antigen screening in older veterans with limited life expectancy. *JAMA Intern Med* 2016;176:654–61.
- 58 Essien UR, He W, Ray A, *et al.* Disparities in quality of primary care by resident and staff physicians: is there a conflict between training and equity? *J Gen Intern Med* 2019;34:1184–91.
- 59 Reid RO, Friedberg MW, Adams JL, *et al.* Associations between physician characteristics and quality of care. *Arch Intern Med* 2010;170:1442–9.
- 60 Lee L, Weston W. The aging physician. *Can Fam Physician* 2012;58:17–18.
- 61 Melfa G, Porello C, Cocorullo G, *et al.* Surgeon volume and hospital volume in endocrine neck surgery: how many procedures are needed for reaching a safety level and acceptable costs? A systematic narrative review. *G Chir* 2018;39:5–11.
- 62 van der Leeuw RM, Lombarts KMJM, Arah OA, *et al.* A systematic review of the effects of residency training on patient outcomes. *BMC Med* 2012;10:65.



## SUPPLEMENTAL MATERIAL

### **‘Physicians’ clinical experience and its association with health care quality: A systematised review’**

Soffien Ajmi<sup>1,2</sup> MD; Karina Aase<sup>2,3</sup> Prof.

1. Department of Neurology, Stavanger University Hospital, Stavanger, Norway
2. Faculty of Health Sciences, University of Stavanger, Stavanger, Norway
3. SHARE - Centre for Resilience in Healthcare, Faculty of Health Sciences, University of Stavanger, Stavanger, Norway

| <b>Supplemental table 1: Included studies on the association between physicians' clinical experience and healthcare quality</b> |                            |  |   |  |                    |
|---|----------------------------|--|---|--|--------------------|
| <b>Reference</b>  | <b>Study design</b>        | <b>Field</b>   | <b>Sample size</b>  | <b>Key results</b>   | <b>Association</b> |
| <b>Dimension of quality: Safety</b>   |                            |  |   |  |                    |
| Atkinson et al., 2018[1]  | Cross-sectional study      | Hospitalist and general pediatricians                          | 95 physicians, 1423 patient encounters                    | Device related adverse event higher among physicians with less years of experience.                                      | Positive           |
| Berk et al., 2008[2]  | Cross-sectional study      | Emergency physicians   | 829 cases   | Physicians with more years of experience less likely to make a cognitive error.  | Positive           |
| McMahon et al., 2012[3]   | Prospective cohort study   | Neurosurgeons  | 3000 cases  | Years of experience was not a risk factor for incidental durotomies.   | Neutral            |
| Theodoro et al., 2010[4]  | Prospective cohort study   | Physicians performing cannulation of the internal jugular vein | 289 attempted cannulations in 282 patients, 77 physicians | Non-linear, U-shaped correlation with better outcomes for low and high-volume physicians.                                | Neutral            |
| Campbell et al. 2019[5]   | Retrospective cohort study | Ophthalmologists   | 499 650 operations  | For composite measure of adverse events, lower risk with more cases, no change with age.                                 | Partially positive |
| Epstein et al., 2013[6]   | Retrospective cohort study | Obstetricians  | 6 704 311 deliveries performed by 5 175 obstetricians     | Significant reduction in complication rates for physicians with more years of training.                                  | Positive           |
| Satkunasivam, R et al., 2020[7]   | Retrospective cohort study | Surgeons   | 1 159 676 patients, 3 314 surgeons                        | Older surgeons had a significantly reduced risk for of complications.  | Positive           |
| Skolka, M. et al., 2020[8]  | Retrospective cohort study | Internal medicine physicians                                   | 31 physicians, 15 933 hospital discharges                 | Higher readmission rates for physicians with a low volume of discharges but no difference with years of experience.      | Partially positive |
| Southern, W. N. et al., 2011[9]   | Quasi-experimental study   | Mixed, all inpatients  | 6572 patients, 59 physicians                              | No difference in readmission rates for physicians with different years of experience.                                    | Neutral            |
| Curtze S. et al., 2012[10]  | Prospective cohort study   | Neurologists   | 1 581 patients  | No difference in rate of intracerebral hemorrhage after thrombolysis for physicians with different volume of treatments. | Neutral            |

|   |  |  |  |  |                    |
|---|--|--|--|--|--------------------|
| Stevens, H. et al., 2018[11]                        | Retrospective cohort study                             | Surgeons                                 | 60 430 patients, 71 physicians         | No statistically significant difference in complication rates across different surgeon age groups.   | Neutral            |
| <b>Dimension of quality: Clinical effectiveness</b> |  |  |  |  |                    |
| Abe et al., 2012[12]                                | Cross-sectional study                                  | Psychiatrists                            | 1036 patients                          | Change in global assessment of function score from admission to discharge had no significant association with years in practice.               | Neutral            |
| Anderson et al., 2017[13]                           | Retrospective cohort study                             | Thoracic surgeons                        | 206 surgeons, 62 851 operations        | Negative association with major morbidity/mortality only for surgeons with >35 years of experience. Neutral for other outcomes and age groups. | Partially negative |
| Ashy et al., 2017[14]                               | Pooled analysis of data from six observational studies | General practitioners                    | 15 282 patients, 2 834 physicians      | Poorer blood pressure control for older physicians, but volume of hypertensive patients associated with better outcomes.                       | Neutral            |
| Bjornsson et al. 2011[15]                           | Prospective cohort study                               | Physicians responding to cardiac arrests | 232 resuscitations and 39 physicians   | Physician experience with real cases does not add to experience from resuscitation training  | Neutral            |
| Chai et al., 2010[16]                               | Retrospective cohort study                             | Thoracic surgeons                        | 3766 patients                          | Lower mortality for older surgeons.  | Positive           |
| Conway et al., 2015[17]                             | Retrospective cohort study                             | Emergency physicians                     | 36 271 patients with 66 933 admissions | Lower mortality in physicians with more years of experience.   | Positive           |
| Funkhouser et al. 2011[18]                          | Retrospective cohort study                             | General practitioners                    | 1901 patients and 133 physicians       | No association between physician age and correct beta blocker prescription after myocardial infarction.  | Neutral            |
| Glassman et al., 2020[19]                           | Retrospective cohort study                             | General practitioners                    | 5053 primary care physicians           | Older physicians associated with lower composite measure of performance  | Negative           |
| Goodwin et al., 2018[20]                            | Cross-sectional study and retrospective cohort study   | Early career hospitalists                | 21 612 hospitalists                    | Mortality lower for second versus first year hospitalist with no change for subsequent years.  | Positive           |
| Haubitz-Eschelbach Andrea et al., 2019[21]          | Retrospective cohort study                             | Emergency room- and ward-physicians      | 18 259 patients, 494 physicians        | Grey-haired physicians compared to those with black or blond hair had lower risk of in-hospital mortality.                                     | Positive           |

|                                   |                                      |  |   |   |                    |
|-----------------------------------|--------------------------------------|--|---|---|--------------------|
| Hsu J.C et al. 2012[22]           | Retrospective cohort study           | Cardiologists performing biventricular device implantation | 272 patients  | Fewer procedural difficulties for more experienced physicians. No difference for failed implantation.                             | Partially positive |
| Huntington et al. 2019[23]        | Retrospective cohort study           | Oncologists administering Rituximab treatments             | 15 110 patients and 2 684 physicians                    | Physicians with higher volume of prior treatments had lower rates of treatment discontinuation (associated with higher mortality) | Positive           |
| Jasuja G. K. et al. 2017[24]      | Cross-sectional                      | Physicians - Several specialties                           | 38 648 providers  | Younger physicians adhered more to guidelines with appropriate testing before medication prescription.                            | Negative           |
| Kerlin et al., 2018[25]           | Retrospective cohort study           | Intensivists   | 345 physicians, 11 268 patients                         | No association between years of experience, volume, and mortality.  | Neutral            |
| Khatana S. A M. et al.2018[26]    | Retrospective cohort study           | Interventional cardiologists                               | 356 interventional cardiologists and 145 247 patients   | Physician caseload significantly associated with mortality but not years of experience.   | Partially positive |
| Lee, H.C. et al., 2009[27]        | Case-control study                   | Psychiatrists  | 87 cases compared to 348 controls                       | Suicide hazard among patients treated by older physicians higher.   | Negative           |
| Levie M. et al., 2011[28]         | Multicenter prospective cohort study | Physicians performing hysteroscopic sterilization          | 578 patients, 37 newly trained and 39 senior physicians | No association with either successful placement or procedural time between newly trained and senior physicians.                   | Neutral            |
| Lindenauer P. K. et al., 2006[29] | Retrospective cohort study           | Internal medicine physicians                               | 13 480 patients, 9 741 physicians                       | Higher physician volumes resulted in lower adherence to guidelines but no difference in mortality.                                | Partially negative |
| McAllister F.A. et al., 2015[30]  | Retrospective cohort study           | Internal medicine physicians                               | 10 046 patients, 149 physicians                         | No association in any of the included outcome measures with years of experience.  | Neutral            |
| Miller E.S. et al., 2018[31]      | Retrospective cohort study           | Obstetricians  | 134 obstetricians and 1 852 patients                    | Lower risk of failed deliveries with more years of experience. No difference in rates of severe perineal lacerations.             | Partially positive |
| Satkunasivam R et al., 2020[7]    | Retrospective cohort study           | Surgeons   | 1 159 676 patients, 3 314 surgeons                      | Older physicians and physicians with a higher volume associated with lower mortality.   | Positive           |
| Slinin Y. et al., 2014[32]        | Retrospective cohort study           | Mixed  | 91 276 patients, 72 734 physicians                      | No association between mortality for hemodialysis patients and physician years of experience or volume.                           | Neutral            |
| Harvey M., et al., 2008[33]       | Prospective cohort study             | Emergency physicians                                       | 1 291 patients  | No association between mortality and senior or resident physicians.   | Neutral            |

|   |                            |  |                                  |  |                    |
|---|----------------------------|--|----------------------------------|--|--------------------|
| Li C. J. et al., 2016[34]                         | Retrospective cohort study | Emergency physicians   | 44 383 non-trauma patients,      | Reduced mortality for physicians with more years of experience.  | Positive           |
| Curtze S. et al., 2012[10]                        | Prospective cohort study   | Neurologists   | 1 581 patients                   | No difference in disability or death for physicians with a higher volume of prior treatments.                    | Neutral            |
| Southern, W. N. et al., 2011[9]                   | Quasi-experimental study   | Mixed, all inpatients  | 6572 patients, 59 physicians     | Higher mortality for physicians with more years of experience.   | Negative           |
| <b>Dimension of quality: Patient-centeredness</b> |                            |  |                                  |  |                    |
| Haubitz-Eschelbach Andrea et al., 2019[21]        | Retrospective cohort study | Emergency room- and ward-physicians  | 18 259 patients, 494 physicians  | Grey-haired physicians had higher patient-perceived quality of care compared to those with blonde or black hair. | Neutral            |
| Nuyen Brian A. et al., 2020[35]                   | Cross-sectional study      | Surgeons   | 36 840 surveys                   | No association between physician age and likelihood to recommend scores.   | Neutral            |
| Obele C.C. et al., 2017[36]                       | Cross-sectional study      | Interventional radiologists  | 2 774 surveys                    | No association between physician age or years of experience and likelihood to recommend scores.                  | Neutral            |
| Seely J.M. et al., 2017[37]                       | Retrospective cohort study | Physicians performing ultrasound guided and vacuum-assisted stereotactic biopsy. | 351 patient interviews           | More years of training for physician associated with less pain and bruising after one of two studied procedures. | Partially positive |
| Fathy et al., 2018[38]                            | Retrospective cohort study | Ophthalmologists and neuro-ophthalmologists                                      | 1342 ophthalmologists            | Older physician had a lower rate of unsolicited complaints.  | Positive           |
| <b>Dimension of quality: Timeliness</b>           |                            |  |                                  |  |                    |
| Li C. J. et al., 2016[34]                         | Retrospective cohort study | Emergency physicians   | 44 383 non-trauma patients       | Older physicians had higher time to order and door to dispositions times than their younger peers.               | Negative           |
| Curtze S. et al., 2012[10]                        | Prospective cohort study   | Neurologists   | 1 581 patients                   | Physicians with a higher volume of prior treatments had reduced door-to-needle time in stroke thrombolysis.      | Positive           |
| Mehrotra, A. et al., 2018[39]                     | Retrospective cohort study | Physicians performing colonoscopies  | 201 physicians, 104 618 patients | The mean adenoma detection rates were higher in physicians with less years of experience.                        | Negative           |
| Harvey, M., et al., 2008[33]                      | Prospective cohort study   | Emergency physicians   | 1 291 patients                   | Physicians with more years of experience had lower waiting times.  | Positive           |

|   |                            |   |  |  |                    |
|---|----------------------------|---|--|--|--------------------|
| Lindenauer, P. K., 2006[29]             | Retrospective cohort study | Physicians treating pneumonia                           | 13 480 patients, 9 741 physicians                | Physician volume not associated with timeliness of administration of antibiotics.                        | Neutral            |
| <b>Dimension of quality: Efficiency</b> |                            |   |  |  |                    |
| Li C. J. et al., 2016[34]               | Retrospective cohort study | Emergency physicians                                    | 44 383 non-trauma patients,                      | Physicians with more years of experience were less likely to order unnecessary tests.                    | Positive           |
| Conway et al., 2015[17]                 | Retrospective cohort study | Emergency physicians                                    | 36 271 patients with 66 933 admissions           | Physician years of experience associated with shorter length of stay in high-risk patients.              | Partially positive |
| Davenport et al., 2020[40]              | Retrospective cohort study | Radiologists assessing initial computed tomography scan | 25 596 patients                                  | Radiologist years of experience associated with lower odds of undergoing subsequent unnecessary imaging. | Positive           |
| Howard, Hockenberry 2019[41]            | Retrospective cohort study | Obstetricians   | 1 658 327 vaginal deliveries, 2200 physicians    | Older physicians associated with higher (unnecessary) episiotomy rates                                   | Negative           |
| Southern W. N. et al., 2011[9]          | Quasi-experimental study   | Mixed   | 6572 patients, 59 physicians                     | Physicians with more years of experience had longer mean lengths of stay.                                | Negative           |
| Courmane S. et al., 2015[42]            | Retrospective cohort study | Emergency physicians                                    | 19 295 patients                                  | Less costs per case for physicians with > 15 years of experience.  | Positive           |
| Ellis S. D., et al., 2015[43]           | Retrospective cohort study | Urologists  | 12 943 patients, 2 138 urologists                | Urologists years of experience was not associated with overuse of medication.                            | Neutral            |
| Mehrotra A. et al., 2012[44]            | Cross-sectional study      | Mixed   | 2 861 093 claims attributed to 12 724 physicians | Lower costs with increasing years of experience and caseload.  | Positive           |
| Piovani D. et al., 2017[45]             | Cross-sectional study      | Community pediatricians                                 | 424 280 patients, 1 164 physicians               | Older physicians associated with higher achievement of targets for antibiotic prescription.              | Positive           |
| Rose-Felker, K. et al., 2016[46]        | Retrospective cohort study | Pediatricians   | 1701 patients, 526 physicians                    | Higher years of experience associated with less appropriate ordering of echocardiography.                | Negative           |
| Schwartz, A. et al., 2019[47]           | Retrospective cohort study | Generalist physicians                                   | 3 159 834 patients and 41 773 physicians         | Increase in rate of low-value services with increasing physician age.                                    | Negative           |
| Tan, A. et al., 2016[48]                | Retrospective cohort study | Primary care providers                                  | 145 320 patients, 3 297 physicians               | Inappropriate ordering of imaging increased with increasing physician age and caseload.                  | Negative           |
| Tang, V. et al., 2016[49]               | Cross-sectional study      | Mixed   | 203 717 patients, 61 874 physicians              | Increasing physician age associated with unnecessary prostate-specific antigen screening.                | Negative           |
| Abe et al., 2012[12]                    | Cross-sectional study      | Psychiatrists   | 1036 patients                                    | No association between length of stay and years of experience.   | Neutral            |

| <b>Dimension of quality: Equity</b> |   |  |  |   |          |
|-------------------------------------|---|--|--|---|----------|
| Essien U. R., et al., 2019[50]      | Retrospective cohort study, propensity-matched sensitivity analysis | Resident and staff primary care physicians | 143 274 patients                         | Residents patients included a higher proportion of typically underserved populations. Residents provided lower quality of care after adjusting for patient factors. | Positive |
| <b>Dimension of quality: Other</b>  |   |  |  |   |          |
| Reid, R.O. et al., 2010[51]         | Retrospective cohort study  | Mixed                                      | 1.13 million patients, 10 408 physicians | Physician age was not associated with higher performance on composite performance score.  | Neutral  |

## REFERENCES

1. Atkinson MK, Schuster MA, Feng JY, Akinola T, Clark KL, Sommers BD. Adverse Events and Patient Outcomes Among Hospitalized Children Cared for by General Pediatricians vs Hospitalists. *JAMA network open*. 2018;1(8):e185658.
2. Berk WA, Welch RD, Levy PD, Jones JT, Arthur C, Kuhn GJ, et al. The effect of clinical experience on the error rate of emergency physicians. *Annals of emergency medicine*. 2008;52(5):497-501.
3. McMahon P, Dididze M, Levi A. Incidental durotomy after spinal surgery: A prospective study in an academic institution - Presented at the 2012 Joint Spine Section Meeting. Clinical article. *Journal of neurosurgery Spine*. 2012;17:30-6.
4. Theodoro D, Krauss M, Kollef M, Evanoff B. Risk factors for acute adverse events during ultrasound-guided central venous cannulation in the emergency department. *Academic emergency medicine : official journal of the Society for Academic Emergency Medicine*. 2010;17(10):1055-61.
5. Campbell RJ, El-Defrawy SR, Gill SS, Whitehead M, Campbell ELP, Hooper PL, et al. Association of Cataract Surgical Outcomes With Late Surgeon Career Stages: A Population-Based Cohort Study. *JAMA ophthalmology*. 2019;137(1):58-64.
6. Epstein AJ, Srinivas SK, Nicholson S, Herrin J, Asch DA. Association between physicians' experience after training and maternal obstetrical outcomes: cohort study. *Bmj*. 2013;346:f1596.
7. Satkunasivam R, Klaassen Z, Ravi B, Fok KH, Menser T, Kash B, et al. Relation between surgeon age and postoperative outcomes: a population-based cohort study. *CMAJ : Canadian Medical Association journal = journal de l'Association medicale canadienne*. 2020;192(15):E385-e92.



8. Skolka M, Lehman E, Khalid M, Hennrikus E. Physician characteristics correlate with hospital readmission rates. *Medicine*. 2020;99(10):e19363.
9. Southern WN, Bellin EY, Arnsten JH. Longer lengths of stay and higher risk of mortality among inpatients of physicians with more years in practice. *The American journal of medicine*. 2011;124(9):868-74.
10. S C. Does time of day or physician experience affect outcome of acute ischemic stroke patients treated with thrombolysis? A study from Finland. *International journal of stroke : official journal of the International Stroke Society*. 2012;7(6):511-6.
11. Stevens H, Carlin AM, Ross R, Stricklen A, Wood MH, Ghaferi AA. Effect of Surgeon Age on Bariatric Surgery Outcomes. *Annals of surgery*. 2018;267(5):905-9.
12. Abe T, Moriya M, Ikeda K, Kuroda K, Hagihara A. Psychiatrist characteristics related to patient outcome in Japan. *The Psychiatric quarterly*. 2012;83(2):221-39.
13. Anderson BR, Wallace AS, Hill KD, Gulack BC, Matsouaka R, Jacobs JP, et al. Association of Surgeon Age and Experience With Congenital Heart Surgery Outcomes. *Circulation Cardiovascular quality and outcomes*. 2017;10(7).
14. Ashy N, Nguyen TN, Denhaerynck K, Gharaibeh M, Alhossan A, Vancayzeele S, et al. Hierarchical Modeling of Patient and Physician Determinants of Blood Pressure Outcomes in Hypertensive Patients with and without Diabetes: Pooled Analysis of Six Observational Valsartan Studies with 15,282 Evaluable Patients. *International journal of chronic diseases*. 2017;2017:9842450.
15. Bjornsson HM, Marelsson S, Magnusson V, Sigurdsson G, Thorgeirsson G. Physician experience in addition to ACLS training does not significantly affect the outcome of prehospital cardiac arrest. *European journal of emergency medicine : official journal of the European Society for Emergency Medicine*. 2011;18(2):64-7.

16. Chai CY, Chen CH, Lin HW, Lin HC. Association of increasing surgeon age with decreasing in-hospital mortality after coronary artery bypass graft surgery. *World journal of surgery*. 2010;34(1):3-9.
17. Conway R, Byrne DG, O'Riordan D, Silke B. Improved outcomes of high-risk emergency medical admissions cared for by experienced physicians. *QJM : monthly journal of the Association of Physicians*. 2015;108(2):119-25.
18. Funkhouser E, Houston TK, Levine DA, Richman J, Allison JJ, Kiefe CI. Physician and patient influences on provider performance:  $\beta$ -blockers in postmyocardial infarction management in the MI-Plus study. *Circulation Cardiovascular quality and outcomes*. 2011;4(1):99-106.
19. Glassman JR, Hopkins DSP, Bundorf MK, Kaplan RM, Ragavan MV, Glaseroff A, et al. Association Between HEDIS Performance and Primary Care Physician Age, Group Affiliation, Training, and Participation in ACA Exchanges. *Journal of general internal medicine*. 2020;35(6):1730-5.
20. Goodwin JS, Salameh H, Zhou J, Singh S, Kuo YF, Nattinger AB. Association of Hospitalist Years of Experience With Mortality in the Hospitalized Medicare Population. *JAMA internal medicine*. 2018;178(2):196-203.
21. Haubitz-Eschelbach A, Durmisi M, Haubitz S, Kutz A, Mueller B, Greenwald JL, et al. The glory of the age is the wisdom of grey hair: association of physician appearance with outcomes in hospitalised medical patients - an observational study. *Swiss medical weekly*. 2019;149:w20162.
22. Hsu JC, Badhwar N, Lee BK, Vedantham V, Tseng ZH, Marcus GM. Predictors of fluoroscopy time and procedural failure during biventricular device implantation. *The American journal of cardiology*. 2012;110(2):240-5.

23. Huntington SF, Hoag JR, Wang R, Zeidan AM, Giri S, Gore SD, et al. Physician Experience and Risk of Rituximab Discontinuation in Older Adults With Non-Hodgkin's Lymphoma. *Journal of the National Comprehensive Cancer Network : JNCCN*. 2019;17(10):1194-202.
24. Jasuja GK, Bhasin S, Rose AJ, Reisman JI, Hanlon JT, Miller DR, et al. Provider and Site-Level Determinants of Testosterone Prescribing in the Veterans Healthcare System. *The Journal of clinical endocrinology and metabolism*. 2017;102(9):3226-33.
25. Kerlin MP, Epstein A, Kahn JM, Iwashyna TJ, Asch DA, Harhay MO, et al. Physician-Level Variation in Outcomes of Mechanically Ventilated Patients. *Annals of the American Thoracic Society*. 2018;15(3):371-9.
26. Khatana SAM, Fiorilli PN, Nathan AS, Kolansky DM, Mitra N, Groeneveld PW, et al. Association Between 30-Day Mortality After Percutaneous Coronary Intervention and Education and Certification Variables for New York State Interventional Cardiologists. *Circulation Cardiovascular interventions*. 2018;11(9):e006094.
27. Lee HC, Lin HC. Are psychiatrist characteristics associated with postdischarge suicide of schizophrenia patients? *Schizophrenia bulletin*. 2009;35(4):760-5.
28. Levie M, Chudnoff SG. A comparison of novice and experienced physicians performing hysteroscopic sterilization: an analysis of an FDA-mandated trial. *Fertility and sterility*. 2011;96(3):643-8.e1.
29. Lindenauer PK, Behal R, Murray CK, Nsa W, Houck PM, Bratzler DW. Volume, quality of care, and outcome in pneumonia. *Annals of internal medicine*. 2006;144(4):262-9.
30. McAlister FA, Youngson E, Bakal JA, Holroyd-Leduc J, Kassam N. Physician experience and outcomes among patients admitted to general internal medicine teaching wards. *CMAJ : Canadian Medical Association journal = journal de l'Association medicale canadienne*. 2015;187(14):1041-8.

31. Miller ES, Battarbee A, Moser A, Gossett DR. Association between physician experience and obstetric outcomes after vacuum delivery. *Journal of Reproductive Medicine*. 2018;63:131-6.
32. Slinin Y, Guo H, Li S, Liu J, Ensrud K, Gilbertson DT, et al. Hemodialysis patient outcomes: provider characteristics. *American journal of nephrology*. 2014;39(5):367-75.
33. Harvey M, Al Shaar M, Cave G, Wallace M, Brydon P. Correlation of physician seniority with increased emergency department efficiency during a resident doctors' strike. *The New Zealand medical journal*. 2008;121(1272):59-68.
34. Li CJ, Syue YJ, Tsai TC, Wu KH, Lee CH, Lin YR. The Impact of Emergency Physician Seniority on Clinical Efficiency, Emergency Department Resource Use, Patient Outcomes, and Disposition Accuracy. *Medicine*. 2016;95(6):e2706.
35. Nuyen BA, Altamirano J, Fassiotto M, Alyono J. Effect of Surgeon Sociodemographics on Patient-Reported Satisfaction. *Journal of the American College of Surgeons*. 2020;231(4):S138.
36. Obele CC, Duszak R, Jr., Hawkins CM, Rosenkrantz AB. What Patients Think About Their Interventional Radiologists: Assessment Using a Leading Physician Ratings Website. *Journal of the American College of Radiology : JACR*. 2017;14(5):609-14.
37. Seely JM, Hill F, Peddle S, Lau J. An evaluation of patient experience during percutaneous breast biopsy. *European radiology*. 2017;27(11):4804-11.
38. Fathy CA, Pichert JW, Domenico H, Kohanim S, Sternberg P, Cooper WO. Association Between Ophthalmologist Age and Unsolicited Patient Complaints. *JAMA ophthalmology*. 2018;136(1):61-7.
39. Mehrotra A, Morris M, Gourevitch RA, Carrell DS, Leffler DA, Rose S, et al. Physician characteristics associated with higher adenoma detection rate. *Gastrointestinal endoscopy*. 2018;87(3):778-86.e5.

40. Davenport MS, Khalatbari S, Keshavarzi N, Connolly M, Kocher KE, Chong ST, et al. Differences in Outcomes Associated With Individual Radiologists for Emergency Department Patients With Headache Imaged With CT: A Retrospective Cohort Study of 25,596 Patients. *AJR American journal of roentgenology*. 2020;214(5):1122-30.
41. Howard DH, Hockenberry J. Physician age and the abandonment of episiotomy. *Health Serv Res*. 2019;54(3):650-7.
42. Cournane S, Conway R, Creagh D, Byrne DG, Silke B. Consultant duration of clinical practice as a cost determinant of an emergency medical admission. *The European journal of health economics : HEPAC : health economics in prevention and care*. 2015;16(5):561-7.
43. Ellis SD, Nielsen ME, Carpenter WR, Jackson GL, Wheeler SB, Liu H, et al. Gonadotropin-releasing hormone agonist overuse: urologists' response to reimbursement and characteristics associated with persistent overuse. *Prostate cancer and prostatic diseases*. 2015;18(2):173-81.
44. Mehrotra A, Reid RO, Adams JL, Friedberg MW, McGlynn EA, Hussey PS. Physicians with the least experience have higher cost profiles than do physicians with the most experience. *Health affairs (Project Hope)*. 2012;31(11):2453-63.
45. Piovani D, Clavenna A, Cartabia M, Bortolotti A, Fortino I, Merlino L, et al. Assessing the quality of paediatric antibiotic prescribing by community paediatricians: a database analysis of prescribing in Lombardy. *BMJ paediatrics open*. 2017;1(1):e000169.
46. Rose-Felker K, Kelleman MS, Campbell RM, Oster ME, Sachdeva R. Appropriate Use and Clinical Impact of Echocardiographic "Evaluation of Murmur" in Pediatric Patients. *Congenital heart disease*. 2016;11(6):721-6.
47. Schwartz AL, Jena AB, Zaslavsky AM, McWilliams JM. Analysis of Physician Variation in Provision of Low-Value Services. *JAMA internal medicine*. 2019;179(1):16-25.

48. Tan A, Zhou J, Kuo YF, Goodwin JS. Variation among Primary Care Physicians in the Use of Imaging for Older Patients with Acute Low Back Pain. *Journal of general internal medicine*. 2016;31(2):156-63.
49. Tang VL, Shi Y, Fung K, Tan J, Espaldon R, Sudore R, et al. Clinician Factors Associated With Prostate-Specific Antigen Screening in Older Veterans With Limited Life Expectancy. *JAMA internal medicine*. 2016;176(5):654-61.
50. Essien UR, He W, Ray A, Chang Y, Abraham JR, Singer DE, et al. Disparities in Quality of Primary Care by Resident and Staff Physicians: Is There a Conflict Between Training and Equity? *Journal of general internal medicine*. 2019;34(7):1184-91.
51. Reid RO, Friedberg MW, Adams JL, McGlynn EA, Mehrotra A. Associations between physician characteristics and quality of care. *Archives of internal medicine*. 2010;170(16):1442-9.