What is the minimum number of specialist anaesthetists needed in low-income and middle-income countries?

Justine I Davies,1,2 Eric Vreede,3 Bisola Onajin-Obembe,4 Wayne W Morriss5,6

ABSTRACT

Introduction The number of specialist anaesthetists in most low-income and middle-income countries is below what is needed to provide a safe quality anaesthesia service. There are no estimates of the optimal number; therefore, we estimated the minimum density of specialist anaesthetists to achieve a reasonable standard of healthcare as indicated by the maternal mortality ratio (MMR).

Methods Utilising existing country-level data of the number of physician anaesthesia providers (PAPs), MMR and Human Development Index (HDI), we developed best-fit curves to describe the relationship between MMR and PAPs, controlling for HDI. The aim was to use this relationship to estimate the number of PAPs associated with achieving the median MMR.

Results We estimated that, in order to achieve a reasonable standard of healthcare, as indicated by the global median MMR, countries should aim to have at least four PAPs per 100 000 population. Existing data show that currently 80 countries have fewer than this number.

Conclusion Four PAPs per 100 000 population is a modest target, but there is a need to increase training of doctors in many countries in order to train more specialist anaesthetists. It is important that this target is considered during the development of national workforce plans, even if a stepwise approach to workforce planning is chosen.

INTRODUCTION

It has been estimated that 5 billion out of 7 billion people globally do not have access to safe, affordable surgical and anaesthesia care when needed and that each year 143 million additional surgical procedures are required in low-income and middle-income countries (LMICs) to save lives and prevent disability.1 To begin to provide for this need, the Lancet Commission on Global Surgery (LCoGS) stated that a massive increase in the specialist surgical, anaesthetic and obstetric (SAO) workforce is required and recommended that all countries should have at least 20 SAO specialists per 100 000 population by 2030.

The need for an adequate surgical workforce was underscored by the adoption, in May 2015, of World Health Assembly Resolution 68.15: ‘Strengthening emergency and essential surgical care and anaesthesia as a component of universal health coverage’.2 Furthermore, in support of universal health coverage (UHC), the Global Alliance for Surgery, Obstetrics, Trauma and Anaesthesia Care (G4 Alliance) has set a target of safe surgical care for 80% of the world by 2030.3 A key to achieving these targets lies in increasing workforce.

Unfortunately, planning for the LCoGS’s 20 SAO specialists per 100 000 population is limited in practical applicability because the proportions of surgeons, anaesthetists and obstetricians—each of which are needed to provide quality surgical care—that should form this specialist SAO workforce were not considered.4,5 More granular information on these proportions is desperately required for benchmarking, advocacy and rational development of the workforce, if we are to achieve UHC by 2030. We aimed to use newly available country-level data on physician anaesthesia...
provider (PAP) density to estimate the minimum number of specialist anaesthetists per 100 000 population required to deliver a reasonable standard of healthcare. We used a similar methodology to that used by the LCoGS to estimate the minimum number of SAO providers.

METHODS
We obtained data on the density of PAPs in individual countries from the World Federation of Societies of Anaesthesiologists (WFSA) Global Anaesthesia Workforce Survey. The survey was conducted during 2015 and 2016, by contacting WFSA member societies and individual providers. Information was collected using an online survey tool and interviews. The WFSA defined PAPs as specialist anaesthetists (anaesthesiologists), trainee specialist anaesthetists or non-specialist physician anaesthetists. The survey found that non-specialist physician anaesthetists accounted for only 2.1% of the total number of PAPs; we therefore used total PAP density as an approximation of specialist anaesthetist density. Similarly to the LCoGS, we used maternal mortality ratio (MMR; maternal deaths per 100 000 live births) as a barometer of country healthcare system functioning. MMR data were obtained from the 2015 World Bank Development Indicator List. Given that a country’s development level is likely to influence MMR, we also explored the effect of including Human Development Index (HDI) as a covariable in our analysis. HDI data for 2015 were obtained from the United Nations database.

Data on PAP densities, MMR and HDI were not normally distributed, so variables are described using median and IQR. To explore the relationship between variables, we transformed the data to enable production of best-fit curves. We examined the relationship between PAP densities and MMR by visual inspection of graphs plotting MMR and PAPs both as continuous variables and with PAPs divided into quintiles. We also derived equations to describe the relationship between PAPs and MMR both without and with HDI as a confounding variable. We then explored the number of PAPs that were associated with the median MMR and describe the number of countries that are below, at, or above our estimated minimum number of PAPs.

RESULTS
We were able to match PAP density, MMR, and HDI data for 168 countries (online supplementary file 1), representing 98% of the world’s population. We found that the median number of PAPs was 4.78 per 100 000 (IQR 0.85–12.70); the median MMR was 52.5 per 100 000 live births (IQR 12–221.75), and the median HDI was 0.73 (IQR 0.56–0.83).

There was an inverse non-linear relationship between PAP densities and MMR (figure 1). Visual inspection of the best-fit curve associating these variables suggests a steep decrease in MMR between 3 and 5 PAPs per 100 000. Analysis of PAP densities by quintile groups is shown in figure 2; visual inspection of this data suggests that a PAP density range of 2.45–6.76 (quintile 3) is associated with a steep decrease in MMR.

On further exploration of the relationship between PAP density and MMR (figure 1), we found that this was best described by using a quadratic equation of the log_{10} transformed variables: log_{10} MMR=2.24−0.72(log_{10} PAP)−0.22(log_{10} PAP)^2. The correlation coefficient (R^2) for this equation was 0.806 (figure 3).

Analysis of the relationship between MMR and HDI revealed a clear association between the two variables. This relationship was best described by plotting the log_{10} MMR against HDI (R^2=0.858) (see figure 1a and 1b in the online supplementary file 1). Because of the clear association between MMR and HDI, we performed a linear regression analysis (with forced
dent predictors of log10MMR; beta weightings and p values

100 000, compared with 77.1% of lower middle-income
low-income countries had a PAP density of less than 4.0 per
100 000. Using World Bank Income Categories, 100% of
000, 12% (21/168) countries had 4.0–7.0 PAPs per 100
274
48% (80/168) countries had less than 4.0 PAPs per 100
286
4 to ‘achieve’ a MMR of 52.5 is a modest target and should
be strived for, given that MMR is around 10 in many high-in-
come countries.

But what does a minimum recommendation of four
specialist anaesthetists per 100 000 mean in real terms?
Globally, the WFSA Workforce Survey estimated that over
8000 additional PAPs would be required to achieve a
minimum density of 1 per 100 000 in all countries, based on
2015 populations. Over 136 000 additional PAPs would be
required worldwide to achieve 5 per 100 000. The majority
of countries in sub-Saharan Africa and some in Asia have
a PAP density of <1 per 100 000 population. Consequently,
for these countries to reach 1 per 100 000, let alone 4 per
100 000, a large investment is required to train more PAPs.
In the short term, this will be next to impossible until the
total number of graduate doctors is also increased. In many
LMICs, there is a general shortage of medical graduates and
this, coupled with anaesthesia’s low profile, results in very
small numbers of doctors training to be specialist anaesthe-
ist.

Longer term planning of a viable anaesthesia work-
force should involve both increasing graduate numbers and
raising the profile of anaesthesiology as a career, as well as
creating positive learning and working environments for
trainees.

Given the number of years to complete the necessary
training and the need to provide care right now, alterna-
tive strategies for delivery of anaesthesia care are a reality

Table 1 Beta weights and p values for association
between log10MMR and HDI, log10PAP, and log10PAP2

<table>
<thead>
<tr>
<th>Beta (unstandardised)</th>
<th>SE</th>
<th>P values</th>
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<tr>
<td>(Constant)</td>
<td>3.926</td>
<td>0.189</td>
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HDI, Human Development Index; MMR, maternal mortality
ratio; PAP, physician anaesthetist provider.

DISCUSSION

We estimate that a minimum number of four PAPs per 100
000 is required to achieve reasonable healthcare, as indicated
by the median MMR (which is a similar MMR to that
currently seen in Argentina or Mauritius). We chose the
MMR to represent a reasonably functioning health system
for several reasons. First, to remain in line with the LCoGS’s
methodology; second, because the data are widely collected
and readily available, and third, the MMR is frequently used
as a measure of the state of countries’ health systems.

Our findings are also in line with a WFSA recommenda-
tion of a minimum PAP density of 5 per 100 000 population.
Although the recommendation of the WFSA was based on
expert opinion rather than on any empirical evidence, it is
reassuring to know that our findings support their
recommendation. We believe that the minimum number of
specialist anaesthetists should be prominent alongside
the LCoGS recommendation of a minimum of 20 specialist
SAO providers.

Following the passage of Resolution 68.15 by the World
Health Assembly in 2015, unanimously calling on member
states to strengthen emergency and essential surgical
care and anaesthesia as a component of universal health
coverage, many countries are now developing National
Surgical Anaesthesia and Obstetric Plans. An estimate of
the minimum number of specialist anaesthetists per 100 000
population is essential for this process. As well as having
value based on our calculations, we argue that a density of
4 to ‘achieve’ a MMR of 52.5 is a modest target and should
be strived for, given that MMR is around 10 in many high-in-
come countries.

We solved this equation using the median HDI of 0.73
and found that a PAP density of 4.04 per 100 000 popula-
tion is associated with the median MMR (52.5).

By various methods, we estimate that approximately
four PAPs are associated with the median MMR, which
is our marker of a reasonably performing health system.
On review of the global PAP density data, we found that
48% (80/168) countries had less than 4.0 PAPs per 100
000, 12% (21/168) countries had 4.0–7.0 PAPs per 100
000, and 40% (67/168) countries had more than 7.0 per
100 000. Using World Bank Income Categories, 100% of
low-income countries had a PAP density of less than 4.0 per
100 000, compared with 77.1% of lower middle-income
countries, 34.1% of upper middle-income countries and
2.2% of high-income countries.

Figure 3 Log10 MMR plotted against log10 PAP. R2 for the
quadratic equation is 0.806. MMR, maternal mortality ratio;
PAP, physician anaesthesia provider.

The relationship between log10MMR and variables
log10PAP, log10PAP2 and HDI was best described using the
following quadratic equation:

\[
\log_{10} \text{MMR} = 3.926 - (\log_{10} \text{PAP} \times 0.27) - (\log_{10} \text{PAP}^2 \times 0.137)
- (\text{HDI} \times 2.798)
\]

\( (R^2 = 0.887)\)

Table 1 Beta weights and p values for association
between log10MMR and HDI, log10PAP, and log10PAP2

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HDI, Human Development Index; MMR, maternal mortality
ratio; PAP, physician anaesthetist provider.
in many LMICs (and some high-income countries). The LCoGS endorsed task sharing as a means to expand the surgical workforce. The commission defined task sharing as a mechanism to maximise human resources and encourage their efficient and safe deployment via the collaborative use of specialist providers, general practitioners, and associate clinicians. Likewise, the WFSA recognises that non-specialist providers will be required in many countries to address workforce deficits. Like the LCoGS, our study only looks at specialist providers and does not attempt to provide an estimate of the required number of non-specialist providers. While we recognise the essential contribution of non-specialist providers in many environments, this does not affect our recommendation of at least four specialist anaesthetists per 100 000 population. In our view, and the view of the WFSA, specialist anaesthetists are required to provide leadership, provide supervision, and drive workforce development.

There are limitations to our analysis. First, our estimates were initially based on visual inspection of graphs, which can be prone to error and bias. However, the LCoGS’s widely cited recommendation on workforce density was also based on visual inspection of a curve plotting the relationship between number of SAO providers and MMR; a specialist surgical workforce density of more than 20 per 100 000 was found to be associated with a steep increase in maternal survival, with the curve flattening out at provider densities above 40 per 100 000. While we used a similar approach to determine the minimum PAP density, we strengthened our finding by estimating the number of PAPs required to achieve a median MMR after mathematically describing the relationship between the two variables and including the effect of HDI.

Second, our use of a median MMR could be considered arbitrary. We recognise that the median MMR is lower than the United Nations Sustainable Development Goals (SDG) target of less than 70 per 100 000 live births. However, our goal was not to see how many anaesthetists are needed to meet the SDG target, but rather how many are needed to form a reasonably functioning health system. We believe that the median MMR is an appropriate measure of this. Third, MMR is just one marker of a well-functioning health system—there are many other such markers. Nevertheless, we chose MMR because it is widely available, reasonably accurately reported, and it was the metric used in the calculations of SAO workforce used by the LCoGS.

CONCLUSION
Our analysis shows that a minimum of four specialist anaesthetist physicians per 100 000 is associated with achieving a median MMR of 52.5. This is a modest target but will nevertheless be seen as highly aspirational in many LMICs. It is important that this target is considered during the development of national workforce plans, even if a stepwise approach to workforce planning is chosen. Every journey starts with a step, and this is a journey we must take if we are to provide safe anaesthesia and surgical care for our patients.

Correction notice This article has been corrected since it published Online First. The second affiliation is corrected to Institute of Applied Health Research (it currently reads Allied Health Research and email address for the corresponding author is updated to j.davies.6@bham.ac.uk).

Contributors EV conceived the idea. JD did the analysis. All authors equally contributed to writing the drafts. Bisola Onajin-Ombebe compiled the reference list.

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REFERENCES