

Global Stroke Statistics 2019

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Abstract

Background: Data on stroke epidemiology and availability of hospital-based stroke services around the world are important for guiding policy decisions and healthcare planning.

Aims: To provide the most current incidence, mortality and case-fatality data on stroke and describe current availability of stroke units around the world by country.

Methods: We searched multiple databases (based on our existing search strategy) to identify new original manuscripts and review articles published between 1 June 2016 and 31 October 2018 that met the ideal criteria for data on stroke incidence and case-fatality. For data on the availability of hospital-based stroke services, we searched PubMed for all literature published up until 31 June 2018. We further screened reference lists, citation history of manuscripts and gray literature for this information. Mortality codes for International Classification of Diseases-9 and International Classification of Diseases-10 were extracted from the World Health Organization mortality database for each country providing these data. Population denominators were obtained from the World Health Organization, and when these were unavailable within a two-year period of mortality data, population denominators within a two-year period were obtained from the United Nations. Using country-specific population denominators and the most recent years of mortality data available for each country, we calculated both the crude mortality from stroke and mortality adjusted to the World Health Organization world population.

Results: Since our last report in 2017, there were two countries with new incidence studies, China ($n=1$) and India ($n=2$) that met the ideal criteria. New data on case-fatality were found for Estonia and India. The most current mortality data were available for the year 2015 (39 countries), 2016 (43 countries), and 2017 (7 countries). No new data on mortality were available for six countries. Availability of stroke units was noted for 63 countries, and the proportion of patients treated in stroke units was reported for 35/63 countries.

Conclusion: Up-to-date data on stroke incidence, case-fatality, and mortality statistics provide evidence of variation among countries and changing magnitudes of burden among high and low-middle income countries. Reporting of hospital-based stroke units remains limited and should be encouraged.

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Introduction

Up-to-date information on stroke burden including incidence, case-fatality and mortality, and the commensurate availability of best-practice services in different countries is important for guiding policy decisions and healthcare planning. We have previously reported stroke statistics by country.^{1,2,3} Understanding the availability of best-practice, hospital-based stroke services is also important to identify whether countries with the greatest need for addressing the stroke burden have resources to reduce the impact of stroke. Stroke units, which offer colocated beds and a specialized interdisciplinary clinical team, are applicable to all types of stroke, and reduce death and disability after stroke.⁴

Aims

Our aims were to: (i) update our repository of the most recent country-specific data on stroke; (ii) determine where data on incidence, mortality, and case-fatality are old, new, or missing; and (iii) determine if hospital-based stroke services are available where there is the most need for them.

Methods

We sought to present incidence, mortality, case-fatality, and data on access to stroke unit for 205 countries (source: www.infoplease.com/countries.html) out of which 194 are recognized by World Health Organization (WHO; source: www.who.int/countries/en/), 192 countries are members of the United Nations (source: www.un.org/en/members/), and 182 countries are recognized by the World Bank (source: www.worldbank.org/en/country). Incidence and case-fatality data were compiled by conducting an updated literature review with a major focus on original manuscripts, using only population-based incidence studies (see Supplementary Table 1). Supplementary searches of mortality and access to stroke units were conducted for this manuscript. Relevant data were also drawn from published systematic reviews on these topics.

Literature search and data extraction for incidence and case-fatality

We searched multiple databases (Medline, Scopus, PubMed, Google Scholar, WHO library, and WHO

regional databases) to identify relevant original manuscripts and review articles published between 1 June 2016 and 31 October 2018 for data on stroke incidence and case-fatality around the globe. The search strategy and predefined inclusion criteria were adapted from our previously published review articles.^{1,2} Population-based studies that met, or potentially met, the ideal criteria (online Supplementary Table 1), and included a thorough overall report of incidence of stroke, incidence among men and women separately, or 7-day, 28-day, or 30-day case-fatality rates were included.

As previously mentioned, citations identified were first screened by title and abstract. After this first screening, the full text was read by a single reviewer (TT). We included only original manuscripts meeting the ideal criteria described above. We also screened the reference lists of included manuscripts, and contacted coauthors to identify any potentially missing original manuscripts that could have data on the incidence or case-fatality of stroke, and would meet the inclusion criteria. For the heat maps on incidence, when there were data from the same country from rural and urban regions, the mean value of these observations is presented for these countries. Information from each manuscript was extracted by one reviewer (TT) and discussed among three reviewers (TT, AGT, and DAC). All authors scrutinized the list of identified manuscripts to assess whether any known manuscripts were missing.

Incidence and mortality by age category

Consistent with our prior methods, we compared incidence and mortality by age of the population.¹ For each country, we determined the proportion of the population aged ≥ 65 years. We then undertook a regression analysis to determine the association between the proportion of the population in this age group and the crude incidence of stroke and/or crude mortality. For incidence studies undertaken over more than one year, we defined the year of the study as being the midyear of the study; the more recent of the two midyears was used when the incidence studies spanned an even number of years. When available, we then matched the population data from the same year for the incidence and/or mortality. When there were no population data available for the defined midyear of the incidence study, we used the closest available year, up to a difference of two years. When there

were no population data available from the WHO database (www.who.int/healthinfo/statistics/mortality_rawdata/en/) within a two-year period, we used population data obtained from the United Nations website,⁵ also within two years of the incidence or mortality data.

Collation and analysis of mortality data

Details of deaths from stroke were obtained from the WHO website (www.who.int/healthinfo/statistics/mortality_rawdata/en/). These data are provided to the WHO by country, having arisen from in-country civil registration systems and coded by their national authority. Many countries also provide their population data to the WHO. We used the latest available data files from WHO, these being updated on 1 December 2018. The files used comprised population denominators, country codes, and mortality. In this analysis, we used mortality coded using the International Classification of Diseases versions 9 and 10 (ICD-9 and ICD-10; see online Supplementary Table 2).

We used the latest year available for mortality. When possible, we combined data on deaths from cerebrovascular disease with the population denominators for the same year to calculate the mortality rate. When the same year was unavailable, for the population data, we used the closest available year but no more than two years apart. When population data were unavailable in the WHO database within this two-year period, we checked the United Nations population data, and used any data that were also available within two years of the mortality data.⁵

We calculated the crude mortality of stroke for each country by dividing the overall deaths from cerebrovascular diseases by the total population of that country, and multiplied by 100,000 to obtain the crude mortality per 100,000 population. We undertook the same calculations for men and women, separately. These crude estimates were used to determine the absolute number of deaths due to stroke. Age-adjusted death rates were then standardized to the WHO world population using the direct method.⁶ The majority of adjustments were made using 5-year age bands, but in instances where mortality data were provided in 10-year age bands, the calculations for these countries were undertaken using these wider age bands. Countries also varied in their report of upper age bands for mortality, ranging from ≥ 65 years to ≥ 95 years. In each instance, we adjusted for age using the maximum number of categories available for each country. The age-adjusted death rates were used to compare death rates between the countries/regions and for estimating the overall stroke-related death rates. The analysis for this aspect of the review was undertaken by author AGT.

Comparison of crude incidence and crude mortality

Using regression analysis, we assessed the association between the crude incidence and crude mortality for each country, using the same year for incidence and mortality, where possible. When the study was conducted over more than one year, we used population data from the middle year of the study, and when there was an even number of years the latter of the two mid-years was used. When countries had not reported population data to WHO, we used the population obtained from the United Nations, described earlier. For countries that had no population data for the year in which the incidence study was conducted, but had population data for other years, the closest available year was used, up to a maximum of two years apart.

Literature search and data extraction for the availability of hospital-based stroke services

We searched the PubMed database to identify original manuscripts and review articles with information about the availability of acute stroke services, using MeSH terms where possible. We took a broad approach to investigate the availability of hospital-based stroke services within countries by searching for literature on stroke units, stroke centers, thrombolysis, endovascular clot retrieval, and stroke telemedicine (see online Supplementary Methods for search terms and screening strategy). As a proxy for the availability of hospital-based stroke services, we interrogated the literature identified for information about the proportion of patients treated in stroke units by country. We also performed a complementary gray literature search, and searched for this information within reports related to national stroke clinical registries known to us from a published systematic review.⁷

In some of the identified literature, the proportion of patients with stroke that received treatment in stroke units within a country was provided directly. Otherwise, the treated proportion was estimated from information about the proportion of hospitals with stroke units and the proportion of patients treated in stroke units within these hospitals. Where information about treatment in a stroke unit and components of stroke units were provided in more than one source, the source with the most current data was preferentially utilized. Using regression analysis, we investigated the relationship between the proportion of patients receiving treatment in stroke units and age-adjusted mortality rates by sex.

Due to the variability in the definition of stroke units, the manuscripts and gray literature identified were used to identify the specific components of stroke units. This was guided by definitions of stroke units used by the European Stroke Organization and Stroke Foundation in Australia (Box 1).

Box 1. Definitions of stroke units

Definition used in Europe—European Stroke Organisation:⁸

A dedicated geographically clearly defined area or ward in a hospital, where stroke patients are admitted and cared for by a multi-professional team (medical, nursing, and therapy staff) who have specialist knowledge of cerebral function, training, and skills in stroke care with well-defined individual tasks, regular interaction with other disciplines, and stroke leadership. This team coordinates care through regular (weekly), multidisciplinary meetings.

Definition used in Australia—National Acute Stroke Services Framework 2019:⁹

1. Colocated beds within a geographically defined unit.
2. Dedicated, interprofessional team with members who have a special interest in stroke and/or rehabilitation. The minimum team would consist of medical, nursing, and allied health.
3. Interprofessional team meet at least once per week to discuss patient care.
4. Regular programs of staff education and training relating to stroke (e.g., dedicated stroke in-service program and/or access to annual national or regional stroke conference).

Results

Overall, there were three studies from two countries in which new incidence data were reported (online Supplementary Tables 3–6). Since our last review, where the most recent data available on mortality were for 2014, there are now new data on mortality for 89 countries (online Supplementary Tables 7 and 8). In addition, new data on case-fatality were reported for two countries (online Supplementary Tables 9 and 10). Additionally, there was information on the presence of stroke units in 63 countries, with information on the proportion of patients with stroke treated in stroke units in 35 of these countries (Table 1 and online Supplementary Table 11).

Incidence

The literature search returned 181 manuscripts (see Figure 1 for selection process). In the first stage of screening, we retrieved 28 potential new manuscripts on stroke incidence. Since our last review,² three new studies were identified, one from China and two from India. In Figure 2, the countries that these new published studies represent are highlighted for overall stroke incidence, while Figure 3 shows all countries that provided sex-specific new and old incidence rates.

In India, the overall crude stroke incidence rate was observed in Ludhiana (2012–2013) at 140/100,000 population per year (Figure 3). In this manuscript, no crude sex-specific incidence was reported. The overall adjusted incidence for India was 145 per 100,000 in Kolkata, and 130 per 100,000 in Ludhiana.^{10,11} These figures are similar to the crude and age-adjusted incidence of stroke in Trivandrum, India, based on a study conducted approximately seven years earlier than the study in Ludhiana and in a similar time frame to the study in Kolkata. In the study from Tianjin, China, the overall age-adjusted incidence of stroke adjusted

to the WHO World standard population was 297 per 100,000 population.¹² This is the greatest age-adjusted incidence rate of all studies conducted using similarly high quality approaches (Figure 4). The sex-specific age-adjusted incidence in China was greater in women than in men (309 vs. 280 per 100,000 population; online Supplementary Table 6).¹¹ In contrast, the new age-adjusted stroke incidence rates were greater in men than in women in India (online Supplementary Table 6).

In regression analyses, there was a strong linear relationship between crude incidence and the percentage of the population aged at least 65 years in both low-middle income countries (LMICs) and high-income countries (HICs) (Figure 5(a)). In contrast, in linear regression analyses undertaken between crude incidence and the year that the studies were conducted, there was no detectable relationship between these two variables in HICs, but a strong relationship for LMICs, indicating that crude incidence has been increasing over time in LMICs, but not in HICs (Figure 5(b)). Indeed, more recent studies conducted in LMICs now have an overall greater age-adjusted incidence of stroke than in most HICs (Figure 6 (a) to (c)).

Mortality

Since our last reviews,^{2,3} where the most recent data available were for 2014, there are now new data for 2015 (39 countries), 2016 (43 countries), and 2017 (7 countries; online Supplementary Tables 7 and 8). Importantly, there were only six countries for which there were no new data available, with the oldest data (1983) being from the Falkland Islands (Malvinas) with four deaths from stroke (Figure 7, and online Supplementary Table 8).

Bulgaria had the greatest crude stroke mortality (312 deaths per 100,000 population per year), with Latvia

Table 1. Presence and access to stroke units by country

High income	Middle income	Low income
No information about the proportion of patients treated in stroke units, but the presence of stroke units was noted		
Belgium	Albania	Central African Republic
Greece	Brazil	Ghana
Iceland	Chile	India
Luxembourg	Columbia	Mauritania
Japan	China	Nigeria
Portugal	Egypt	Ukraine
Qatar	Macedonia	
Singapore	Malta	
South Korea	Pakistan	
USA	Saudi Arabia	
	South Africa	
	Sri Lanka	
Information about the proportion of patients treated in stroke units was noted		
Australia 49.5%	Argentina 5.7%	–
Austria 67%	Belarus 60%	
Canada 23%	Bosnia and Herzegovina 35%	
Denmark 51%	Bulgaria 10%	
Finland 62%	Croatia 50%	
France 33%	Czech Republic 85%	
Germany 70%	Estonia 61%	
Ireland 54%	Georgia 1%	
Israel 5%	Hungary 30%	
Italy 33%	Latvia 77%	
New Zealand 39%	Lithuania 20%	
Norway 90%	Moldova 20%	
Slovenia 35%	Poland 70%	
Spain 23%	Romania 1%	
Sweden 87.5%	Russia 13%	
UK 83%	Serbia 40%	
	Slovakia 20%	
	Thailand 25%	
	Turkey 30%	

These data reflect the best estimate of the proportion of patients with stroke that are treated in stroke units within these countries. Bolded estimates were obtained from <http://strokeeurope.eu/>. Countries were classified by income level according to the World Bank.

being second (258/100,000 population/year; Figure 7 and online Supplementary Table 8). Romania and the Russian Federation also had high crude mortality (218/100,000 population/year for Romania and 216/100,000/year for the Russian Federation). All of the mortality data for these top four countries were relatively recent (2013–2016), although data for the Russian Federation were reported using a broad category of “cerebrovascular disease” and so may overestimate deaths from

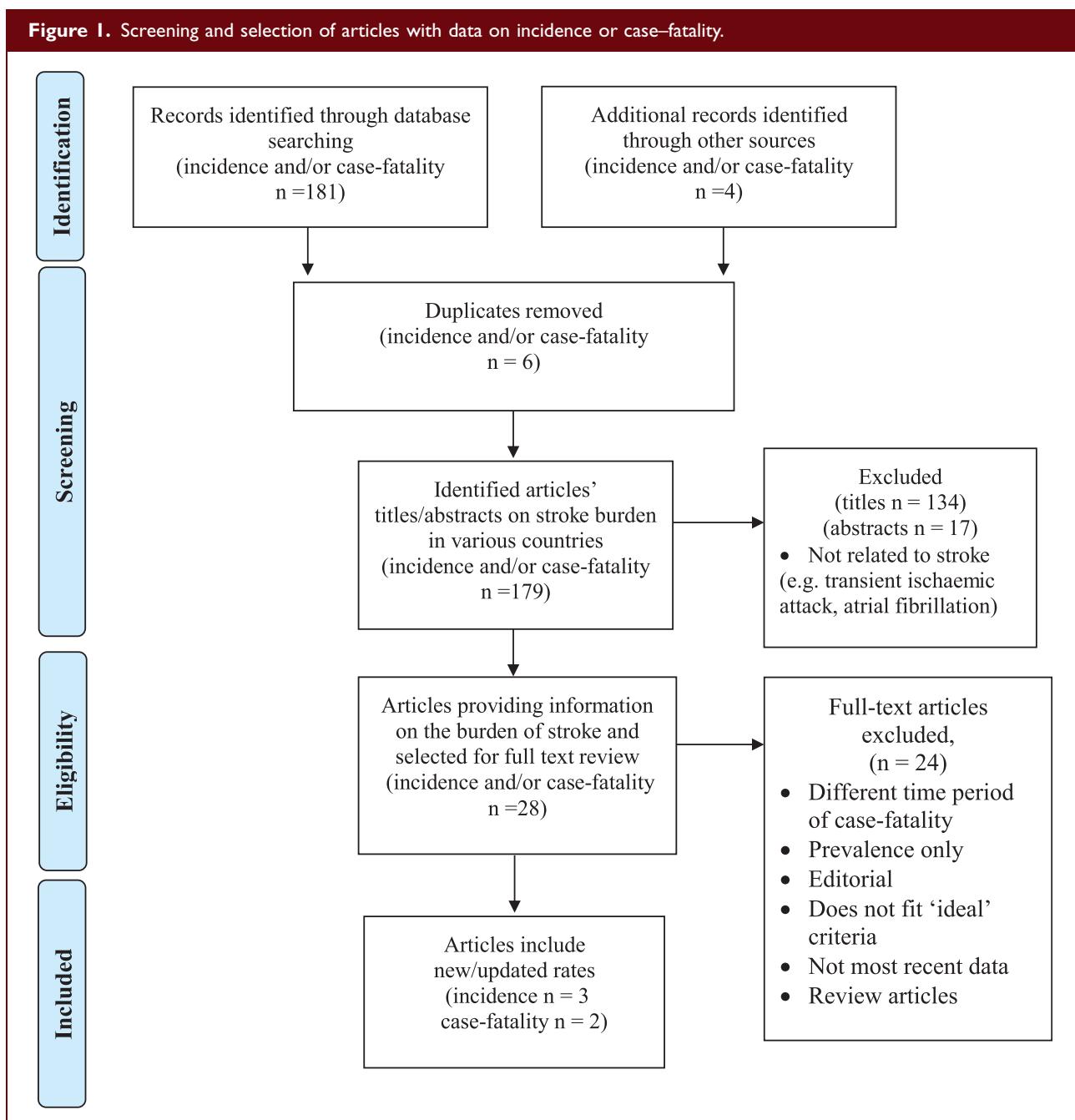
stroke. Kazakhstan had previously had the greatest crude mortality (300/100,000/year), but it now sits at 38th (72/100,000/year) among those countries for which data are available, a considerable decline over this 12-year period from 2003 to 2015. Countries with new crude mortality at the lower end of the spectrum include Qatar (3.9/100,000/year in 2016), Honduras (4.7/100,000/year; 2013), Bahrain (6.2/100,000/year; 2014), and Morocco (6.9/100,000/year; 2014). Haiti also had a low mortality rate, but data were more than 10 years old (1.7/100,000/year; 2004).

Countries such as Sweden and Germany have very low crude mortality even though the proportion of the population aged ≥ 65 years is large (Figure 8(a)). The countries with the greatest mortality rates with a relatively small proportion ($\sim 10\text{--}12\%$) of the population aged ≥ 65 years include the Republic of Moldova (2016) and the Republic of North Macedonia (2013). The relationship between crude mortality and the proportion of the population aged ≥ 65 years is steeper in LMICs (slope = 10.51, 95% confidence interval (CI) 8.25–12.77; $p < 0.001$) than in HICs (slope = 4.36, 95% CI 2.72–6.00; $p < 0.001$). There is no evidence for a linear relationship between crude mortality and the year the mortality data were collected, either for LMICs or HICs (Figure 8(b)).

When adjusting mortality rates for stroke to the new world population (Figures 9 and 10), only three of the countries that were within the top 10 largest rates in our past review remained in the top 10. These include the Falkland Islands (Malvinas; 1983), selected rural regions in China (2000) and the Russian Federation (2013). There were 49 incidence studies among 29 countries that reported both crude incidence of stroke (all ages included), as well as mortality data to the WHO. There was a strong linear relationship between incidence and mortality from stroke in HICs (slope = 1.00, 95% CI 0.59–1.42; $p < 0.001$), but not in LMICs (slope = 0.19, 95% CI –0.38 to 0.76, $p = 0.46$; Figure 11).

Case-fatality

The literature search returned 179 manuscripts (see Figure 1 for selection process). Only two new manuscripts met our strict inclusion criteria. In both studies, only 28-day case-fatality rates were reported. In Tartu (Estonia), the overall case-fatality reported at 28 days was 26%. Sex-specific case-fatality rates were greater in women than in men. In Ludhiana (India), the overall case-fatality rate reported at 28 days was slightly lower at 22%. No other countries reported new case-fatality rates at either 7, 28, or 30 days (online Supplementary Table 10).



The data on case-fatality of stroke provide evidence for considerable variation among countries (Figures 12 and 13).

Availability of hospital-based stroke services

Of the 7177 manuscripts identified, there were 121 unique manuscripts and reports that met the inclusion criteria (Supplementary Results and Supplementary Figure 1). Further details are provided in the online

Supplement. There was information on the presence of stroke units in 63 countries (Figure 14). There was some information from 35 of the 63 countries on the proportion of patients with stroke treated in stroke units (Table 1). There appeared to be an inverse relationship between proportion of patients treated in stroke units and stroke mortality rate in women (Figure 15(a)) and in men (Figure 15(b)). Coverage varied greatly, with as few as 1% of people with stroke being treated in a stroke unit, and up to 90% in other regions (Figure 16).

Figure 2. World map showing availability of studies with overall incidence. Old studies indicate those that were included in the previous review, while new studies indicate those published since that review.² The map is based on crude and/or adjusted incidence of stroke irrespective of age restriction or adjustment method. The countries highlighted are therefore different to those in Figure 4.

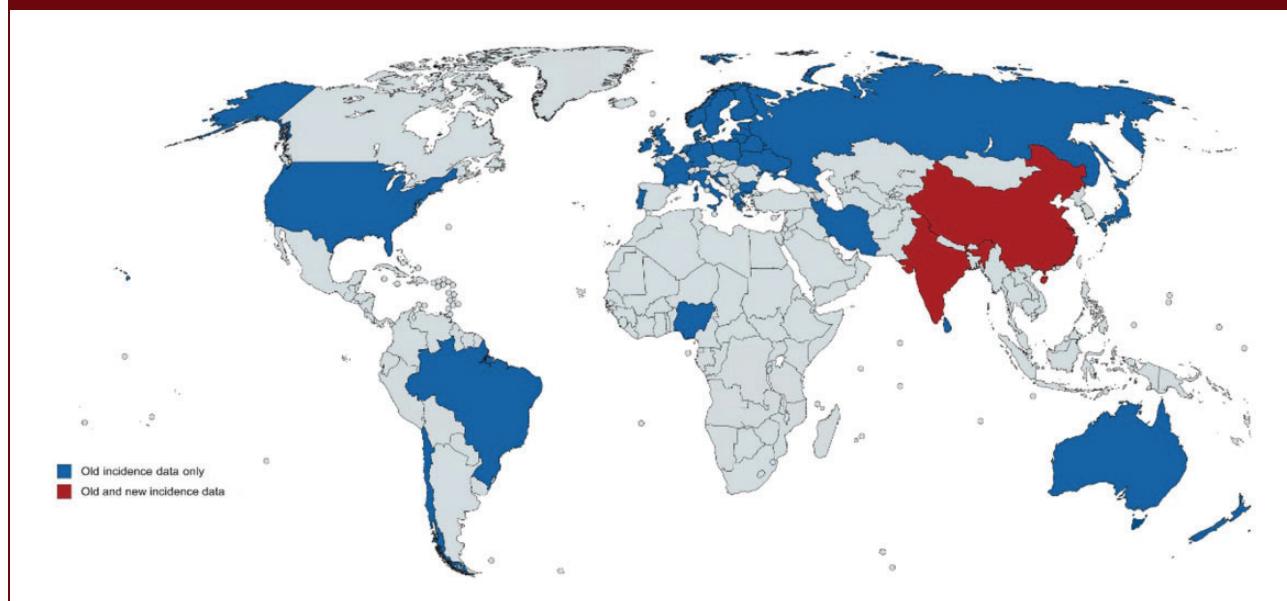
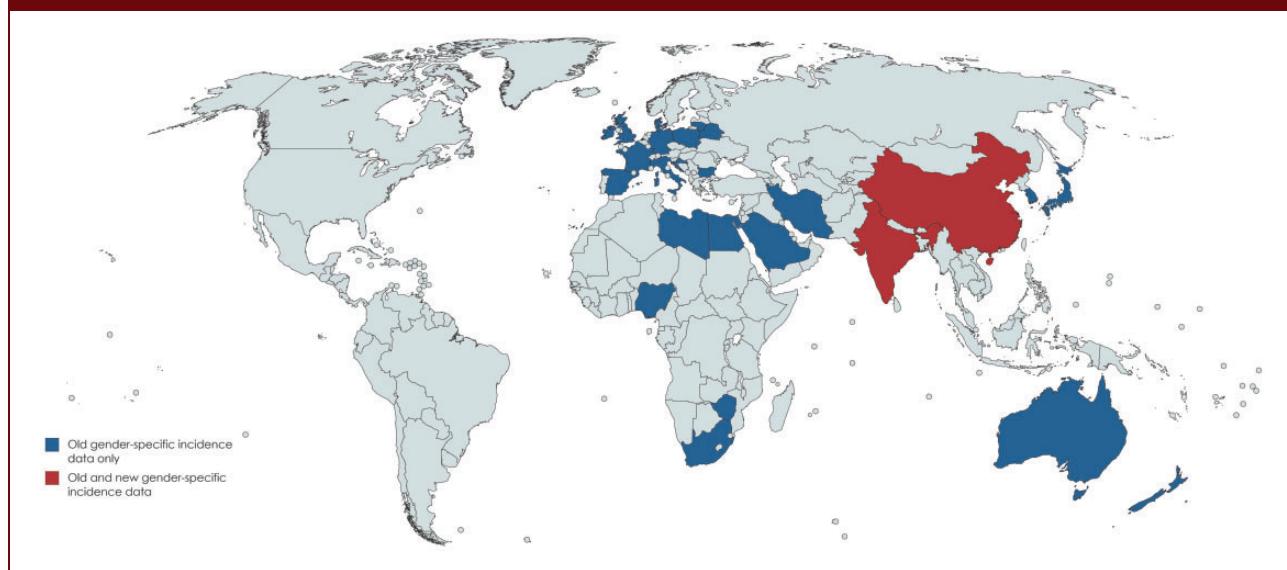
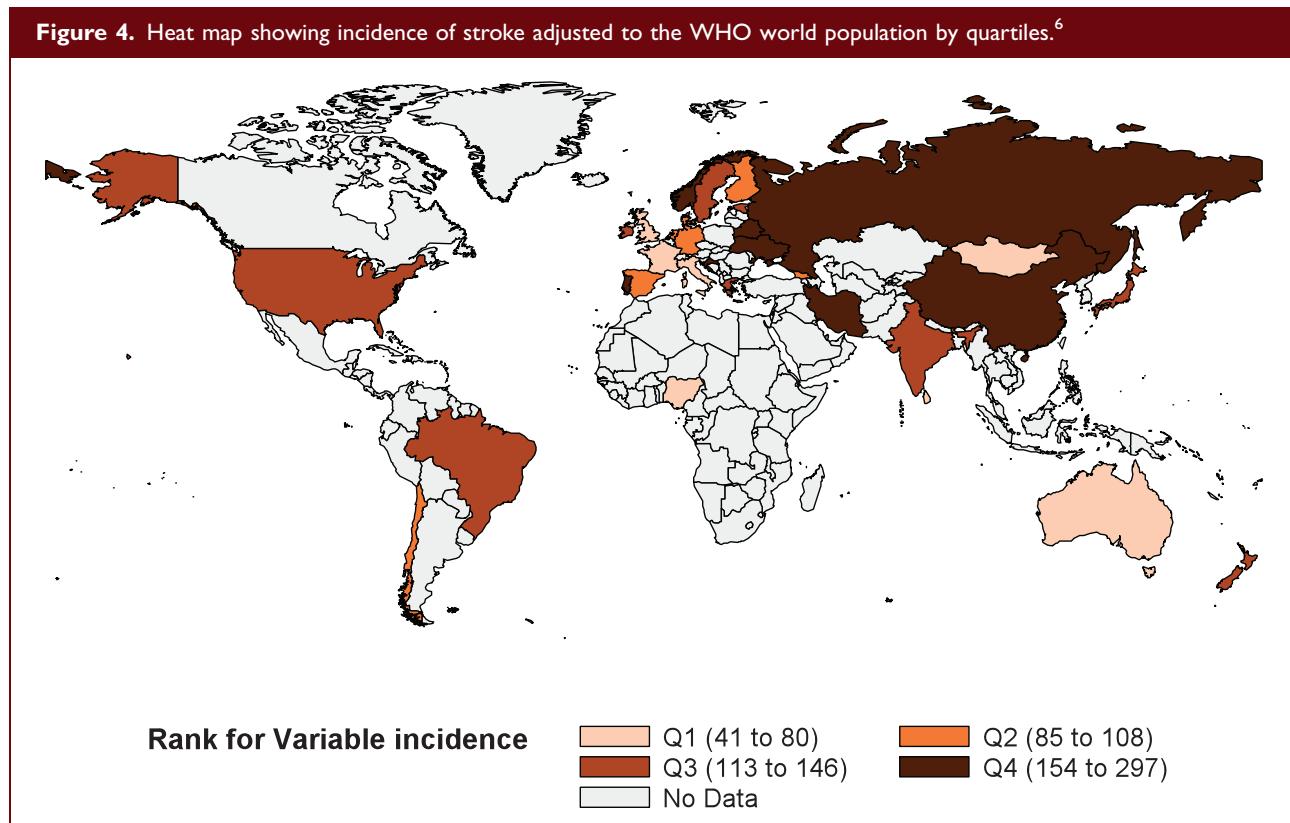
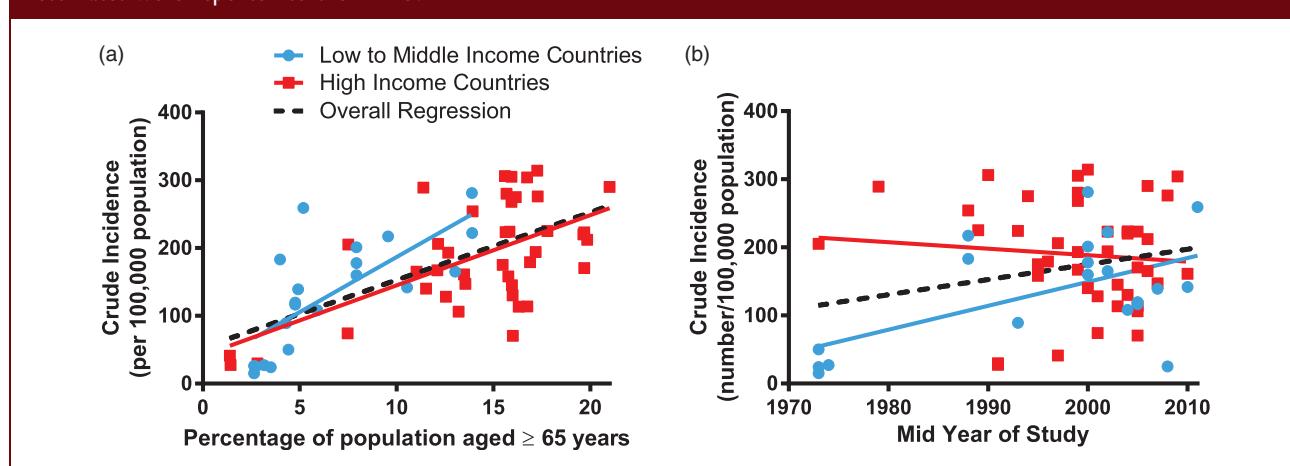


Figure 3. World map showing availability of studies with sex-specific incidence. The map is based on crude and/or adjusted incidence of stroke irrespective of age restriction, or adjustment method, hence it is different to Figure 4.



There were only 16 countries that had some information in the identified literature on the components of stroke units. These were: Argentina, Australia, Brazil, Canada, Denmark, Finland, Hungary, India, New Zealand, Norway, Poland, Portugal, Qatar, Thailand, Turkey, and the UK, while Austria, Germany,

Luxembourg, and the Czech Republic had certified stroke units. There was information that stroke centers within Brazil were certified by the Joint Commission International and the Canadian Stroke Network and that stroke units in several countries were adherent to guidelines for acute stroke care within their country.

Figure 4. Heat map showing incidence of stroke adjusted to the WHO world population by quartiles.⁶**Figure 5.** Crude incidence from stroke according to (a) the proportion of the population aged ≥ 65 years (overall, $Y = 9.992 \times X + 52.85, p < 0.001$; LMICs, $Y = 16.24 \times X + 24.39, p < 0.001$; HICs, $Y = 10.36 \times X + 41.4, p < 0.001$) and (b) the midyear that the study was conducted (overall, $Y = 2.222 \times X - 4270, p = 0.03$; LMICs, $Y = 3.509 \times X - 6868, p = 0.005$; HICs, $Y = -0.9544 \times X + 2097, p = 0.56$). These are for all countries that have reported crude incidence, and for which population estimates were reported to the WHO.²¹⁻³⁴

Discussion

In this article, we present an updated comprehensive review of the most recently available stroke incidence

and case-fatality data for individual countries, and important updates of mortality data available from the WHO database. For the first time we overlay country-level information on the proportion of

Figure 6. Incidence of stroke, adjusted to World Health Organization world population, for studies completed between (a) 1974 and 1994, (b) 1995 and 2003, and (c) 2004 and 2014.^{11,21–23,25–31,35–45} High-income countries are shown in the white bars, and low- and middle-income countries are shown in the blue bars.

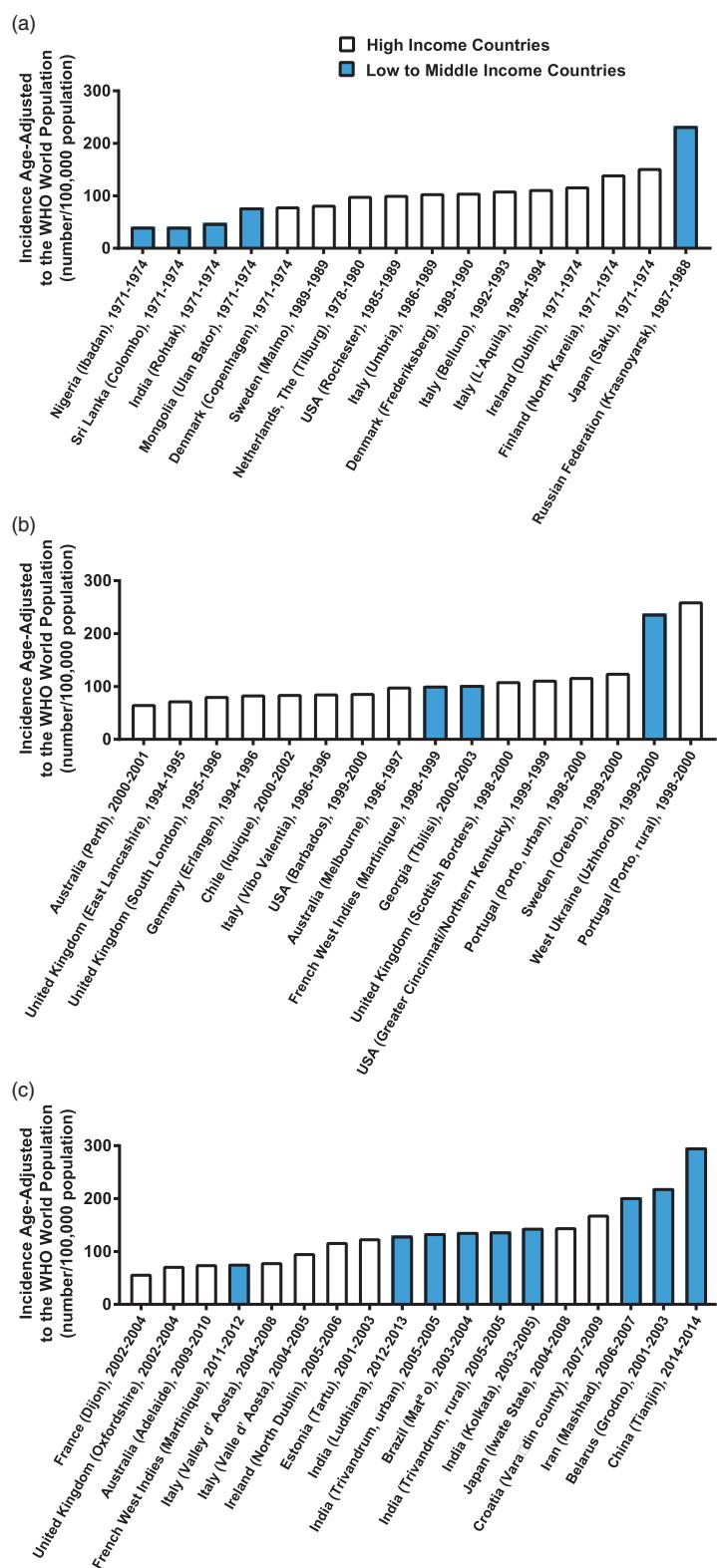


Figure 7. Crude mortality (per 100,000 population) from stroke in the most recent year reported to the World Health Organization, ordered according to the average mortality for men and women. Note that mortality data for China are for selected regions only and represent <10% of all deaths in the country.

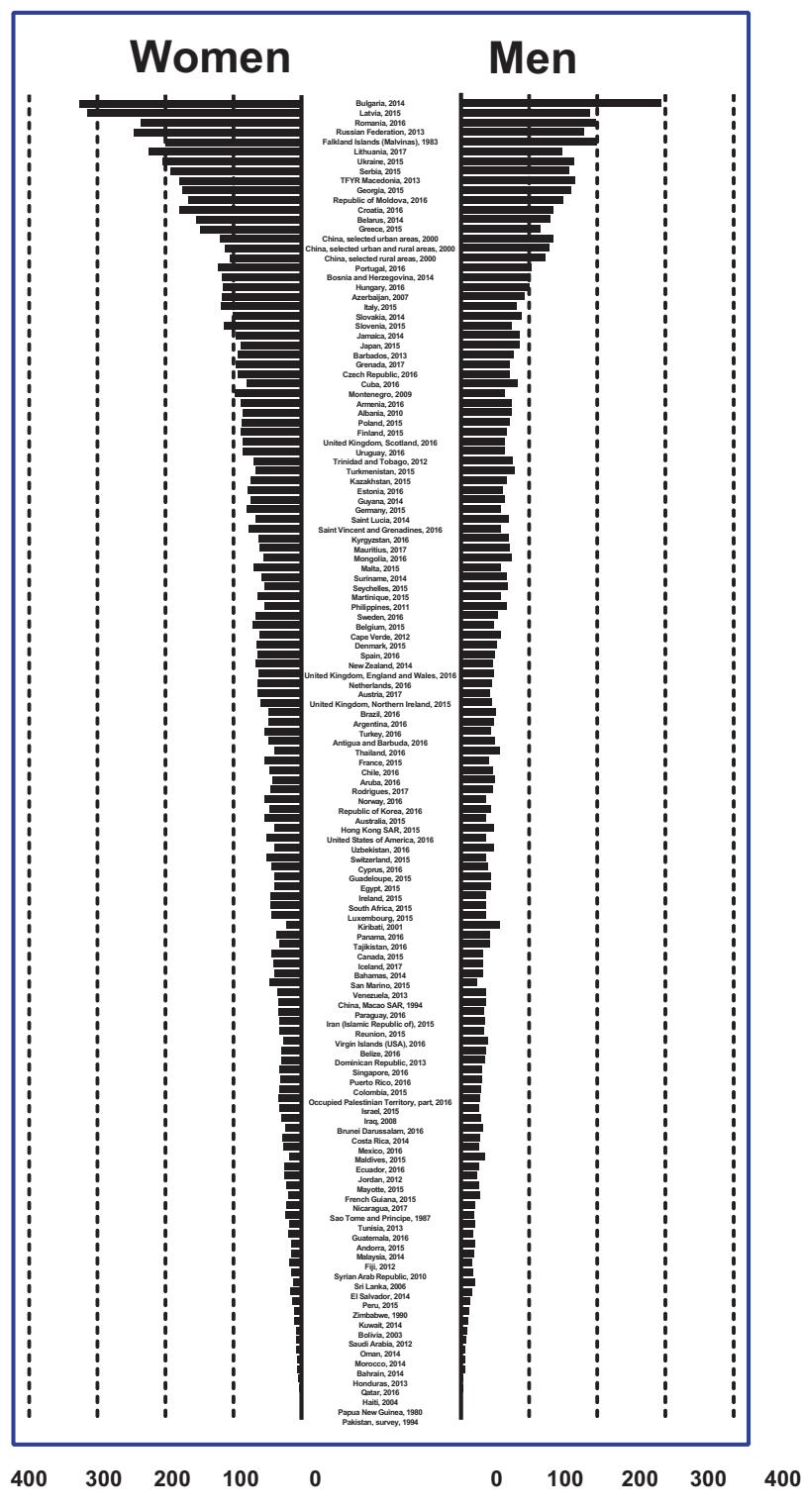
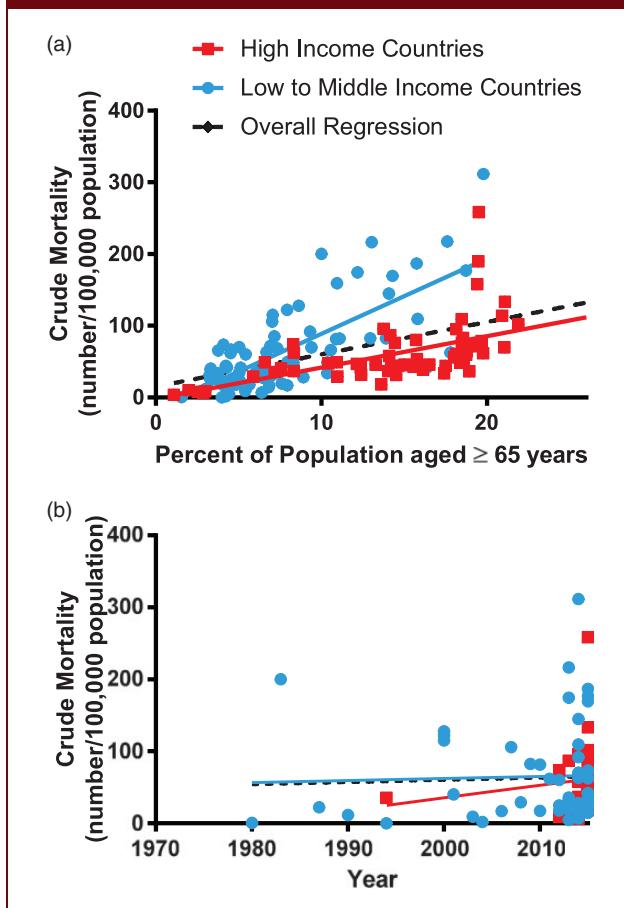


Figure 8. Crude mortality from stroke according to (a) the proportion of the population aged at least 65 years (LMICs: $Y = 10.51 \times X - 416.38, p < 0.0001$; HICs: $Y = 4.36 \times X - 1.838, p < 0.0001$) and (b) the year (LMICs: $Y = 0.2881 \times X - 513.9, p = 0.75$; HICs: $Y = 1.756 \times X - 3476, p = 0.36$). These are for all countries that have reported mortality to the World Health Organization, and are for the most recent year reported for each individual country. If there were no population denominators for the country within two years of the mortality data, the population data from the United Nations were used.



patients treated in stroke units with stroke mortality statistics.

We found three new studies to provide more up-to-date information on stroke incidence relevant to India and China, both hugely populous LMICs. The lack of new information on stroke incidence, and case-fatality elsewhere is evident. It is important to consider the need for new, or existing, well-designed, community-based stroke surveillance studies to be conducted in regions where high-quality data are unavailable or are outdated. This is particularly important when changes are rapid, as shown by the strong correlation between the crude incidence of stroke and the year the study was

conducted for LMICs but not HICs. This highlights the ongoing shift in the burden of stroke from HICs to LMICs.

In addition, overall geographic disparities in stroke incidence, mortality, and case-fatality seem to be ongoing. The variation in burden of stroke in relation to incidence, case-fatality, and mortality is mixed for HICs and LMICs and is influenced by the recency and availability of the data.

We identified more recent mortality data for a larger number of countries. These more recent data highlight the considerable improvement in mortality over time for some countries. For example, Kazakhstan has moved from top place, having the greatest mortality, to 38th among those countries for which data are available, a considerable decline over this 12-year period from 2003 to 2015. For some countries, the mortality rates were small, and this may in part be explained by the fact that data are old and so do not reflect any recent changes. For example, data from Haiti were more than 10 years old (1.7/100,000/year; 2004), so it is possible that mortality from stroke has increased since that time. Our findings could also be affected by problems with routine coding of stroke. There is evidence that temporal decline in stroke mortality can be affected by changes in local coding practices.^{13,14} Some of the countries with high mortality report data using a broad category of "cerebrovascular disease," and so their mortality rates may be overestimated. Such countries should be encouraged to report mortality using the same codes to enable better comparability between countries.

When adjusting mortality rates for stroke to the new world population, it is notable that for two of the three countries that remained in the top 10 largest rates since our past review, the data are very old. These include the Falkland Islands (Malvinas; 1983), and selected rural regions in China (2000). Other countries that still have among the greatest mortality, even though more recent data are available, include Bulgaria, the Republic of North Macedonia, Guyana, Republic of Moldova, Kyrgyzstan, Latvia, and the Ukraine. This highlights the importance of having the most up-to-date data available so that relevant policy decisions can be made.

It is important that patients with stroke have access to treatment in stroke units. Patients who receive treatment in a stroke unit have a reduced risk of death and dependence compared to treatment in an alternate ward setting.⁴ We found that the majority of countries did not have information about stroke units. Many more countries may have stroke units, but there was no published information about this or it was published in a language other than English. The countries identified that had information about stroke units were mainly HICs with aging populations. In LMICs,

Figure 9. Age-adjusted mortality (per 100,000 population) from stroke in the most recent year reported to the World Health Organization, ordered according to the average mortality for men and women. Note that mortality data for China are for selected regions only and represent <10% of all deaths in the country.

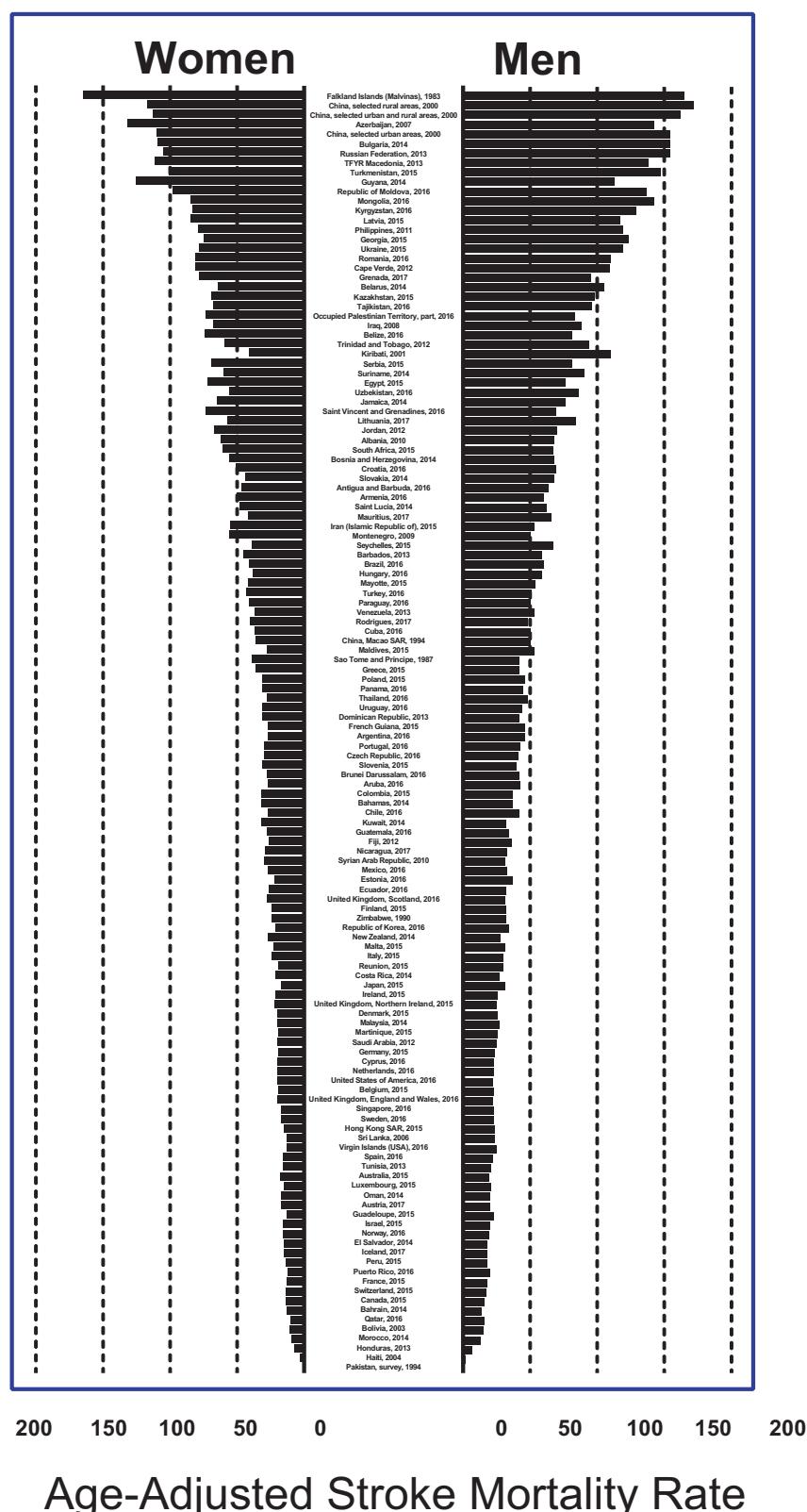


Figure 10. Heat map showing mortality (per 100,000 population) from stroke adjusted to the WHO world population, by quintiles.⁶

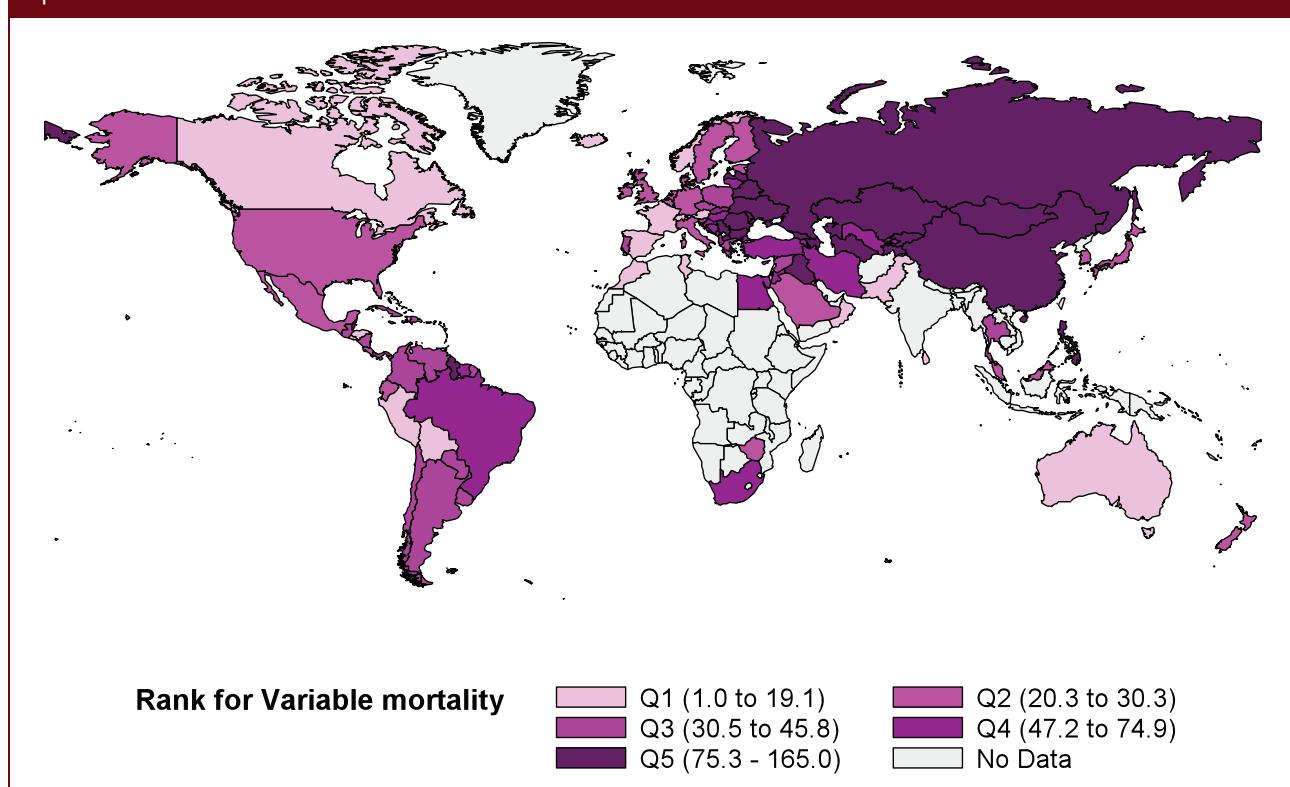
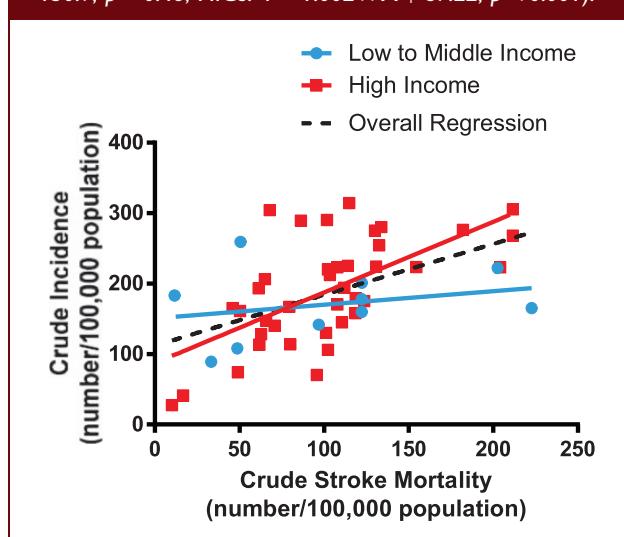


Figure 11. Regression of crude mortality from stroke versus incidence. These are for all countries that have reported mortality to the World Health Organization, and also have assessed the incidence of stroke for a similar year ($Y = 0.724 \times X + 112, p < 0.001$; LMICs: $Y = 0.1914 \times X + 150.9, p = 0.46$; HICs: $Y = 1.002 \times X + 87.22, p < 0.001$).



stroke units are less common and are mainly privately funded.¹⁵ While the burden of stroke mainly comes from LMICs,¹⁶ stroke proportionally contributes less to the burden of disease in these countries when compared to HICs.¹⁷ Therefore, the development of stroke units may not be a current government priority.

Variability in the definition of stroke units and stroke centres needs to be considered when interpreting these data. Countries have their own guidelines for the delivery of acute stroke care and what constitutes a stroke unit may not be consistent. However, these guidelines were not scrutinized for this work. While some work has been done to standardize definitions of these stroke services (e.g., certification in Europe, and adoption of certification from other countries like in Brazil), there are regional differences in terminology. For example, some stroke units are specific to acute stroke care and others to rehabilitation as described by the Stroke Unit Trialists' Collaboration.⁴

We assumed that patients treated in stroke centers were treated in a stroke unit since a major component of stroke centers (comprehensive and primary) is a stroke unit. We also assumed that stroke units were present based on the use of this term. However, stroke units may be self-described without information

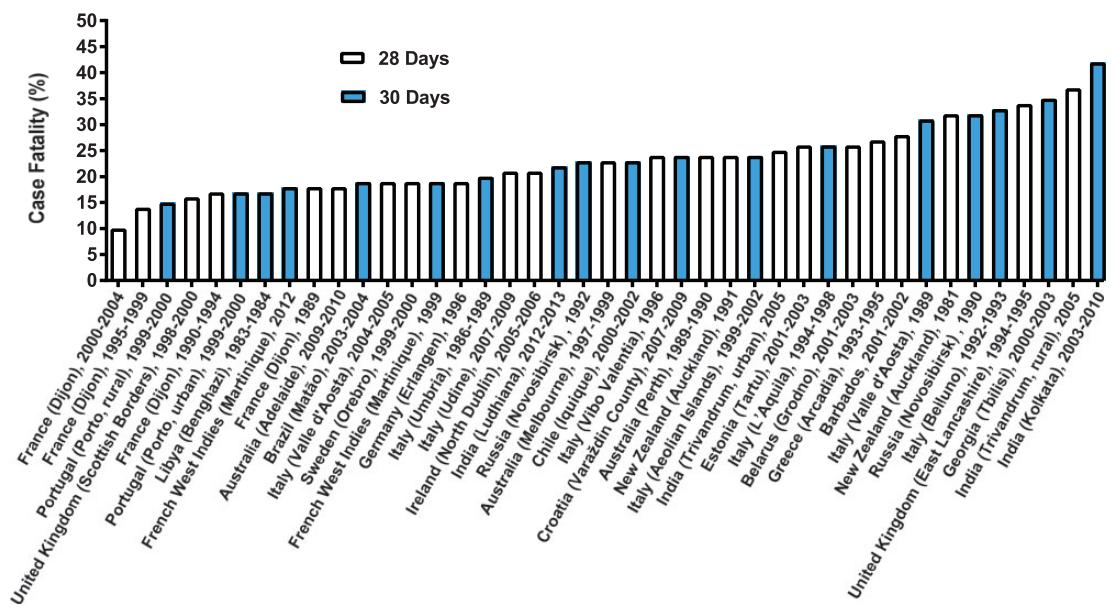
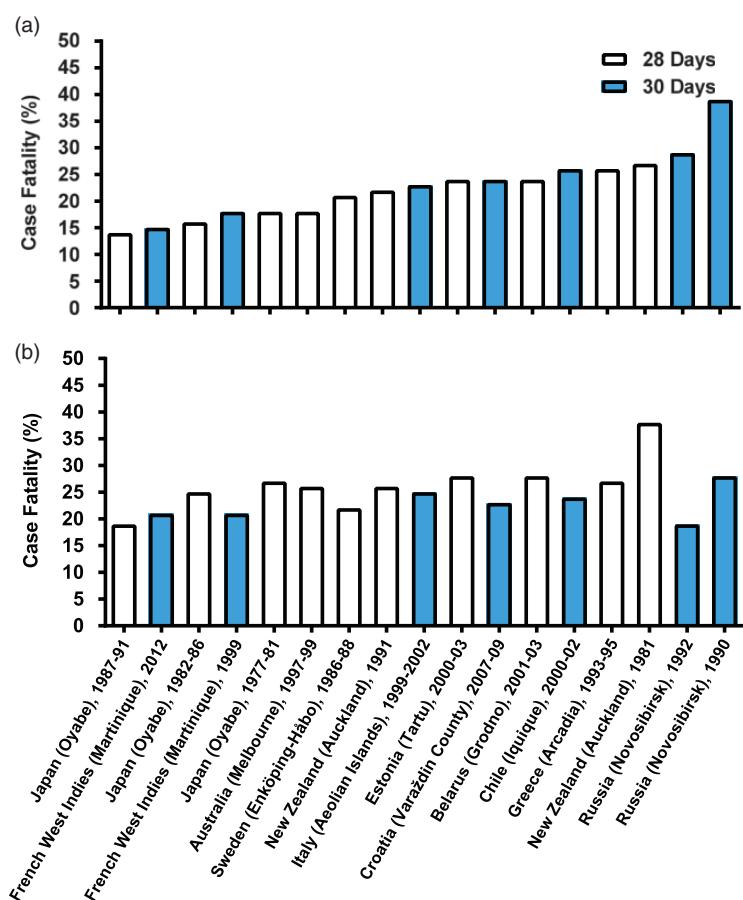
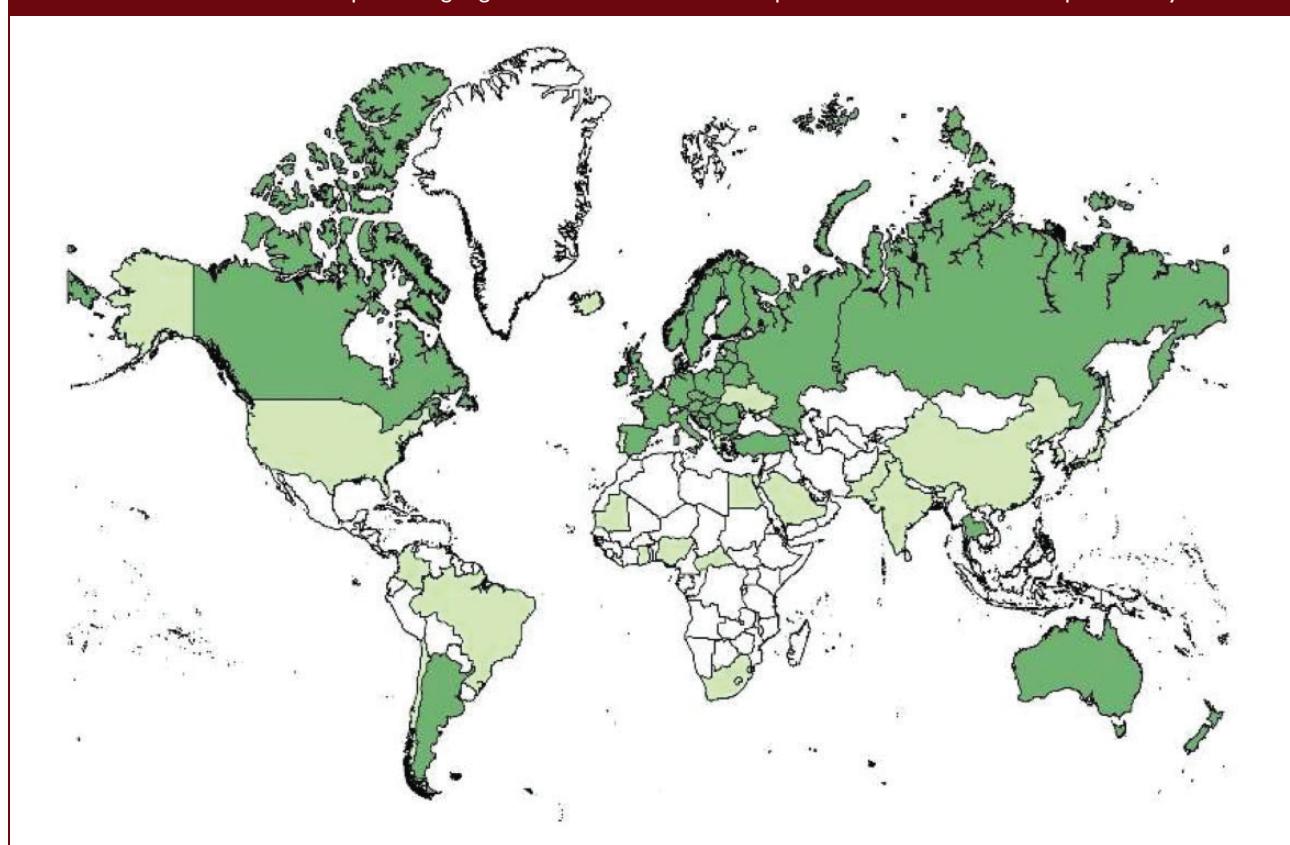
Figure 12. Overall 28-day and 30-day case-fatality of stroke that are reported in countries.^{11,22,26–30,40–43,46–66}**Figure 13.** Comparison of gender-specific 28-day and 30-day case-fatality of stroke in (a) men, and (b) women, that are reported in countries.^{27,29,30,49,56,57,61,63,64,67–69}

Figure 14. Presence of stroke units in all countries. Dark green: countries in which the proportion of people with stroke who have access to stroke units is reported, light green: countries in which the presence of stroke units is reported only.



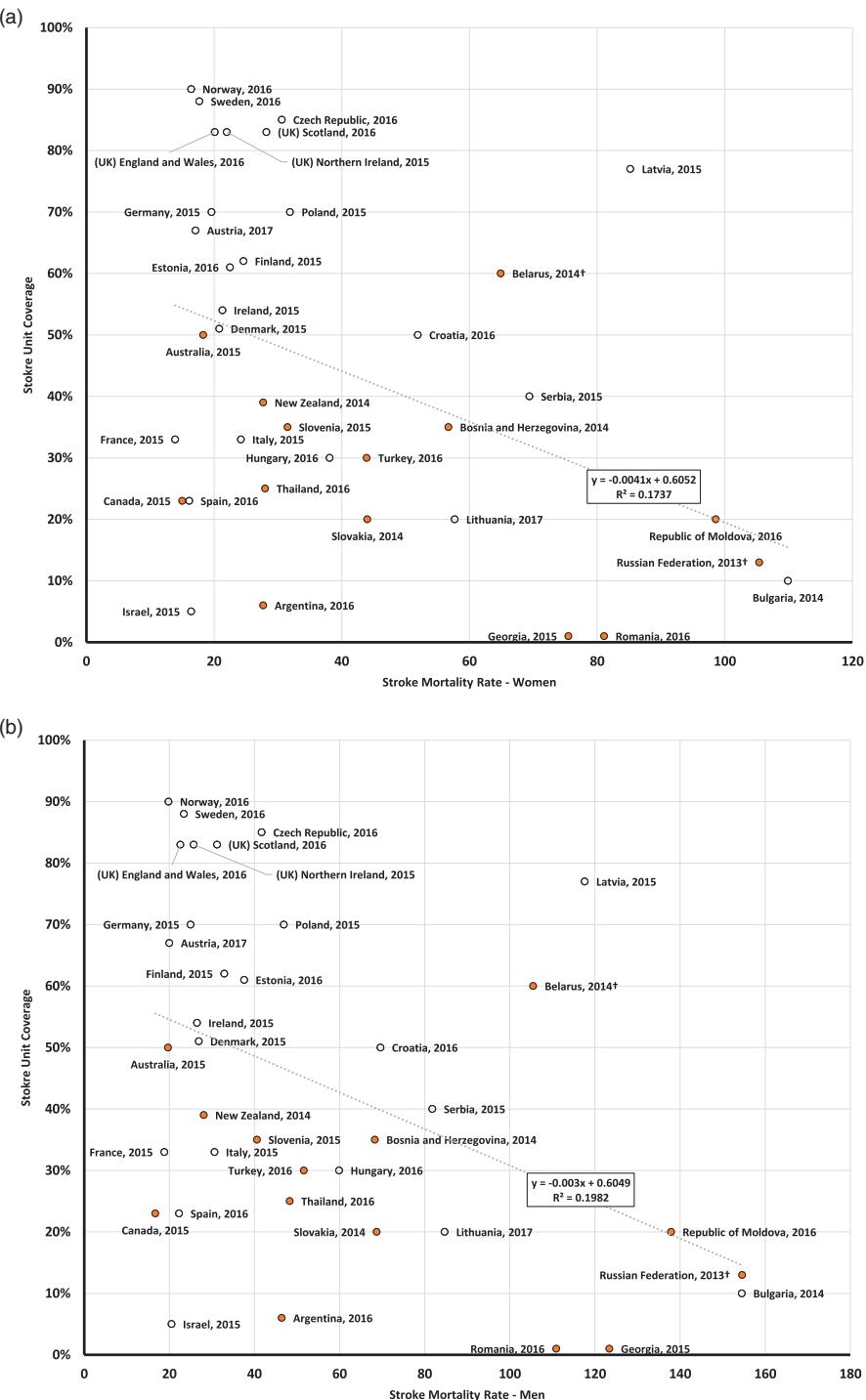
about what qualifies as a stroke unit. This may be particularly relevant for LMICs. There is evidence that even within HICs, some stroke units are not fulfilling criteria for stroke units while being self-described as one.^{18,19}

Our search strategy for identifying the availability of acute stroke services was deliberately broad, with search terms related to reperfusion therapies and telemedicine included, in order to capture information about stroke units. The rationale was that the provision of reperfusion therapies and telemedicine outside of a setting with a stroke unit is uncommon. Our search strategy was also not refined based on the date of publication. Therefore, changes to the definition of stroke units over time and outdated information are a limitation of this work.

Considerable work has been conducted in Europe by the Stroke Alliance For Europe, where information on the presence and proportion of patients receiving treatment in stroke units was already present for several countries.²⁰ Efforts to replicate this work in other regions would be productive to determine countries that require development of acute stroke services. When reporting quality of acute stroke services, including information about the components of stroke unit care and the proportion of patients treated in stroke units should be encouraged.

In conclusion, recent data on incidence, case-fatality, and mortality statistics provide evidence of variation among countries and changing magnitudes of burden among HICs and LMICs. We further highlighted that the reporting of hospital-based stroke services remains limited and should be encouraged.

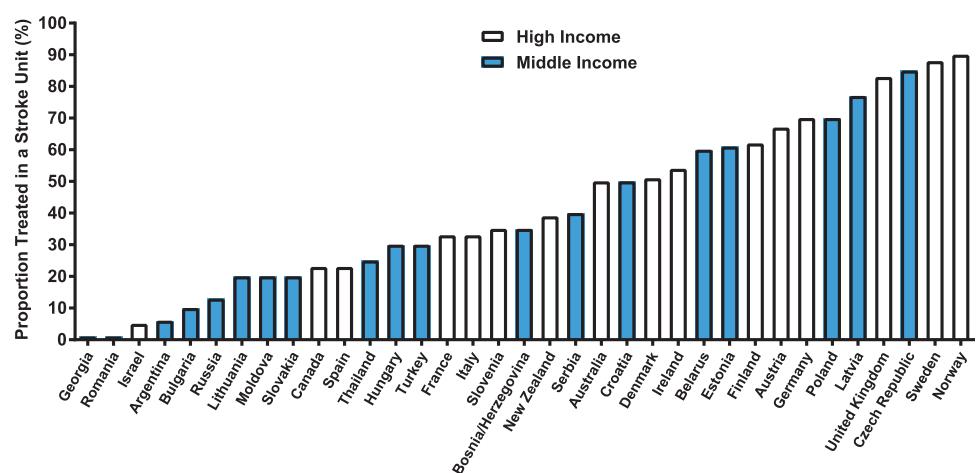
Figure 15. Comparison of stroke mortality* and stroke unit coverage in (a) women and (b) men. *Stroke mortality rate estimates based on mortality and population data reported to the World Health Organization since 1980, with age adjustment using the New World population. When the population data from the World Health Organization were more than two years away from the mortality data for the same country, we used population data from the United Nations. Thus all population data were within two years of the corresponding mortality data.



†Codes for deaths include all cerebrovascular disease deaths, and so may overestimate stroke mortality rates.

Estimates of stroke unit coverage for countries represented with a hollow circle come from the Burden of Stroke in Europe Report.²⁰

Linear regression line plotted between mortality rate and stroke unit coverage.

Figure 16. Estimated proportion of patients with stroke treated in a stroke unit.

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The source of the mortality data is the World Health Organization (WHO) Mortality database, and the WHO is responsible only for the provision of the original information. The analyses, interpretations and conclusions are the authors alone not the WHO.

Authors' contributions

JK undertook the literature search and data collection, and wrote parts of the first draft of the manuscript and approved the final version. TT undertook the literature search and data collection, and wrote parts of the first draft of the manuscript and approved the final version. GAD contributed to the design of the study, interpreted the data, revised the manuscript and approved the final version. GH contributed to the design of the study, undertook some of the analyses, interpreted the data, revised the manuscript, and approved the final version. VJH contributed to the design of the study, interpreted the data, revised the manuscript, and approved the final version. PMH contributed to the design of the study, interpreted the data, revised the manuscript, and approved the final version. VLF interpreted the data, revised the manuscript, and approved the final version. BN interpreted the data, revised the manuscript, and approved the final version. MO contributed to the design of the study, interpreted the data, revised the manuscript, and approved the final version. JP interpreted the data, revised the manuscript, and approved the final version. LL interpreted the data, revised the manuscript, and approved the final version. DAC contributed to conception and design of the study, wrote parts of the first draft of the manuscript, and approved the final version. AGT contributed to conception and design of the study, undertook the data analyses, wrote parts of the first draft of the manuscript, and approved the final version.

Declaration of conflicting interests

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Supplemental material

Supplemental material for this article is available online.

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