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Global, regional, and national burden and quality of care index of endocarditis: the global burden of disease study 1990–2019

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# 1 Title: Global, Regional, and National Burden and Quality of Care Index of

# 2 Endocarditis: The Global Burden of Disease Study 1990-2019

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# 4 Abstract:

Aims: Endocarditis accounts for significant morbidity and mortality. Timely diagnosis and prompt
treatment are of paramount importance for optimal patient outcome. However, only few studies
have assessed quality of care (QoC) in endocarditis. We aimed to describe QoC and changes in
epidemiological features of endocarditis from 1990-2019.

9 Methods: Using primary indices of mortality, incidence, years of life lost, years lived with 10 disability, and disability-adjusted life year, obtained from the Global Burden of Disease Study 11 2019, we calculated four secondary measures. Principal component analysis was performed to 12 calculate QoC index (QCI), scored on a scale of 0-100 with higher values indicating better QoC, 13 for different locations, age groups, and genders from 1990-2019.

**Results:** The all-ages incidence rate of endocarditis was estimated to increase significantly from 1990 to 2019, while mortality rate did not change. The age-standardized QCI was 73.6% globally, with higher values in high- than low-income countries. High-income North America (82.0%) and Asia Pacific (81.1%) had the highest QCI, whereas Eastern Europe (43.3%) had the lowest. Globally, the 30-49 and 95+ age groups had the highest (91.3%) and the lowest (71.7%) QCI,

1 respectively. In most countries, particularly those with lower socio-demographic index, women

2 had better QCI.

Conclusion: This is the first global assessment of QCI, shedding light on the current trends and highlighting the necessity of improving the endocarditis quality of care, mainly by timely case detection, adherence to antibiotic prophylaxis guidelines, utilizing targeted antibiotics and advanced treatments, in the African region and resolving gender inequality in selected countries. **Keywords:** burden, cardiovascular diseases, endocarditis, epidemiology, health status indicators, quality of health care

# 9 Background

Endocarditis, frequently involving cardiac valves (either native or prosthetic) or cardiac implantable devices, is commonly caused by infection of the endocardium. Infective endocarditis (IE) is estimated to affect 3 to 10 per 100,000 population per year and the hospital charges may be up to \$120,000 per patient <sup>1</sup>. While IE is an old condition first described more than 350 years ago, it is still a monumental challenge with significant changes over the past century in the patients' demographic features, risk factors, and microbiological etiologies, particularly after development of antibiotics and controlling rheumatic heart disease <sup>1, 2</sup>.

First attempts in assessing and improving Quality of Care (QoC) in cardiovascular diseases were made in the late 1990s. Since then, improving and quantifying QoC has become increasingly critical. The World Health Organization (WHO) defines QoC as "the degree to which health

services for individuals and populations increase the likelihood of desired health outcomes" <sup>3</sup>. The
inequity in QoC, both between and within countries, has attracted serious attention recently.
Approximately 8 million deaths are attributed to inappropriate health care quality for treatable
diseases (like cardiovascular diseases such as IE) in low- and middle-income countries, which
shows a considerable disparity between countries in different socio-economic levels <sup>4</sup>. Moreover,
demographic factors such as age and gender may affect QoC.

Only few studies have investigated QoC and adherence to IE guidelines <sup>5, 6</sup>. A recent review of autoptic cases between January 1983 and December 2006 in Italy found that diagnosis of IE was missed in a substantial proportion of the patients implying the critical role of improving QoC for endocarditis <sup>7</sup>. Lack of global data on the assessment of QoC in endocarditis calls for a thorough investigation of QoC, its trend in the past decades, and the disparity between genders, different age groups, and countries in various socio-economic levels.

In this study, we investigated QoC in endocarditis at global, regional, and national levels using the results of the Global Burden of Disease (GBD) 2019 study <sup>8</sup>. Quantifying QoC helps clinicians and policymakers understand the current trends and plan improvements.

16 Methods

#### 17 Data resources

We retrieved the GBD data from 1990 to 2019 from the Institute for Health Metrics and Evaluation
(IHME) website. According to the 10<sup>th</sup> revision of the International Classification of Diseases

1 (ICD-10) system, endocarditis is identified under diagnostic codes of B33.21, I33-I33.9, I38-I38.0,

2 and I39-I39.9 for death and I33-I33.9, I38-I39.9 for new cases <sup>9, 10</sup>. This study is in concordance

3 with the Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER

4 guidelines).

# 5 Quality of care index (QCI)

6 The protocol of calculating QCI was previously reported and employed to assess QoC in several

7 cardiovascular diseases and cancers <sup>11</sup>.

8 In summary, using six primary indices of mortality, incidence, prevalence, years of life lost

9 (YLLs), years lived with disability (YLDs), and disability-adjusted life years (DALYs), we defined

10 four secondary indices as below:

11 (1) Mortality to Incidence Ratio (MIR) =  $\frac{\text{Mortality}}{\text{Incidence}}$ : A greater mortality rate for a fixed 12 incidence rate results in a higher MIR, which has been validated for ranking QoC and healthcare 13 performance in several cancers <sup>12, 13</sup>.

14 (2) Prevalence to Incidence Ratio (PIR) =  $\frac{\text{Prevalence}}{\text{Incidence}}$ : Higher values of PIR may indicate 15 reduced incidence and better prevention.

16 (3) YLL to YLD Ratio =  $\frac{YLL}{YLD}$ : The higher the YLL to YLD Ratio, the disease causes more fatality 17 than disability.

1 (4) DALY to Prevalence Ratio =  $\frac{DALY}{Prevalence}$ : Greater values of DALY to Prevalence Ratio show

2 increased burden (both YLL and YLD) for a fixed prevalence rate.

To calculate the QCI, we used principal component analysis (PCA), which is a multivariate statistical algorithm to reduce the dimensionality of the data by calculating a linear combination of different datasets while preserving most variation <sup>14</sup>. As the first component extracted from PCA was the most comprehensive summary of the secondary indices, it was considered the QCI. QCI was scored on a scale of 0 to 100, with higher scores showing more advanced QoC.

8 Socio-Demographic Index (SDI) is a summary measure of "average income per person,
9 educational attainment, and total fertility rate", with higher numbers showing more advanced
10 socio-economic development <sup>15</sup>. According to the SDI scale, countries are classified into high,
11 high-middle, middle, low-middle, and low SDI.

We calculated QCI for 204 countries, 6 WHO regions, and 21 GBD regions, in addition to the
global scale. QCI was also quantified for the categories classified according to the SDI and world
bank income levels.

#### 15 Age and gender disparity

Age was classified in five-year intervals (infants under 1, 1-4, 5-9, ..., 90 to 95, and 95 plus years of age). Age-standardized measures as rates for 100,000 population were used to generate the secondary indices mentioned earlier.

1 We calculated gender disparity ratio (GDR) to evaluate the variation of QoC in males and females.

2 GDR values close to one indicate the least inequity in QoC between the two genders, and values

3 higher or lower than one represent better QoC in females or males, respectively.

4 
$$GDR = \frac{QCI \text{ for females}(\mathbf{P})}{QCI \text{ for males}(\mathbf{P})}$$

#### 5 **Decomposition analysis**

To investigate the components affecting the endocarditis incidence rate, we further performed a 6 7 decomposition analysis of the endocarditis incidence trend between 1990 and 2019. Population growth, population aging, and an increase in age-specific endocarditis incidence rates are the major 8 contributors to the incidence trend. Using decomposition analysis, we estimated the contribution 9 of the age-specific endocarditis incidence rates changes while controlling for population size and 10 age structure. Expected endocarditis incidence in 2019 was calculated in two steps: (1) accounting 11 for the population growth in 2019 (applying the age-specific endocarditis incidence rates in 1990 12 into the 2019 population size) and (2) accounting for both population growth and age structure 13 change in 2019 (applying the age structure and age-specific endocarditis incidence rates in 1990 14 to the 2019 population size and age structure). The contribution of population aging was calculated 15 as the difference of the estimates calculated in steps one and two. By calculating the difference 16 between the observed values and the expected rates according to population growth and aging, the 17 contribution of changes in the age-specific rates of endocarditis incidence was estimated <sup>11</sup>. We 18

1 reported the contribution of each factor to the overall change of the incidence rate as the percent

2 of change.

#### 3 Socio-demographic index (SDI)

The SDI, ranging from 0 to 100, indicates socio-demographic development by incorporating
lagged distributed income per capita, average years of education, and total fertility rate <sup>16</sup>. We used
the SDI to classify the 204 GBD countries and territories into quintiles based on predefined
thresholds.

#### 8 Statistical analysis

9 We presented the values of the primary index variables with a 95% uncertainty interval (UI). As

10 discussed earlier, the PCA mathematical method was employed to generate QCI. Trend shifts and

11 estimations were considered significant if there was no overlap between the UIs over time.

12 All statistical analyses and plot illustrations were performed by R statistical package v 4.0.4

13 (http://www.r-project.org/, RRID: SCR\_001905)<sup>17</sup>.

#### 14 **QCI validation analysis**

We investigated the correlation between QCI and universal health coverage (UHC) effective coverage index, which quantifies the extent to which high-quality healthcare services are provided to all people needing them without any financial difficulties <sup>18</sup>. We applied a mixed-effect model with QCI as the dependent variables, while independent variables included inpatient and outpatient

1 healthcare utilization, mortality, and prevalence. Countries were considered as random effects. We

2 estimated a Pearson's correlation coefficient of 0.60 (acceptable level) using this model.

# 3 **Results**

#### 4 Epidemiological description of endocarditis from 1990-2019

Globally, the age-standardized incidence rate of endocarditis was not significantly different 5 between 2019 and 1990. However, the number of incident cases in all ages significantly rose from 6 478,002 (95% UI= 393,388-572,422) in 1990 to 1,090,526 (913,497-1,296,291) in 2019 (Figure 1, 7 Table 1). Decomposition analysis showed that increased age-specific incidence, with a higher 8 value in men globally, was the major contributor (67.3%) of the increased incidence rate (Table 9 2). The demographic features of patients with endocarditis seem to be changing. From 2008 to 10 2016, the age-standardized incidence rate of endocarditis was significantly higher in men. 11 However, this difference was not significant before and after this period (Figure 1). Notably, the 12 75+ age group had higher incidence, prevalence, and mortality rates than the under 60. Moreover, 13 the incidence rate in the 75+ age group was significantly higher in 2019 than that of 1990 (86.8 14 (66.0-110.6) versus 38.7 (28.5-49.9) per 100,000 people) (Supplementary material online, S1). 15

Worldwide, endocarditis is estimated to account for 0.9 (0.6-1) age-standardized deaths and 21.9
(17.2-24.6) DALYs per 100,000 population in 2019. Mortality and burden (DALY, YLL, and
YLD) did neither significantly differ between males and females nor throughout the investigated
period (2019 versus 1990) (Table 1). In low-SDI countries, estimated age-standardized deaths

decreased by 13.3% and DALYs decreased by 18.6% from 1990 [0.9 (0.6-1.3) and 31.2 (19.4-43.5)] to 2012 [0.8 (0.6-1.1) and 25.4 (18.4-32.1)]. Conversely, in high-SDI countries, estimated age-standardized deaths and DALYs rose by 71.4% and 45.4%, respectively, from 1990 [0.7(0.6-1.1) and 16.3 (13.5-24)] to 2007 [1.2 (0.6-1.5) and 23.7 (13.9-272)] (Table 1, Supplementary material online, S2).

6 Endocarditis had heterogeneous epidemiological features in different locations. The lowest and 7 highest age-standardized prevalence rates were found in low or low-middle and high SDI countries 8 throughout the investigated period, respectively. Moreover, the age-standardized incidence rate 9 was also lower in low SDI countries than in other SDI levels. Similarly, low-middle SDI countries had lower age-standardized incidence rates than the middle, high-middle, and high SDI until 2016. 10 Comparably, age-standardized incidence rates in low and low-middle income countries were lower 11 than global, upper-middle, and high-income countries between 1991 and 2019 (according to the 12 world-bank income level classification). However, age-standardized death rate and DALYs per 13 100,000 population did not significantly differ between different SDI levels throughout the 14 investigated period. Epidemiological descriptions of endocarditis in different WHO regions in 15 1990, 1997, 2007, and 2019 are described in Supplementary material online, S3. 16

#### 17 **Quality of care index**

The estimated global, age-standardized QCI score for both sexes was 73.6% (76.5% for females)and 73.1% for males) in 2019. Figure 2a depicts the global distribution of QCI. Thailand, Canada,

Luxembourg, Sweden, and the United States (US) had the highest age-standardized QCI scores 1 for both sexes with 87.2%, 84.9%, 83.7%, 82.3%, and 81.6%, respectively in 2019. The most 2 considerable drop in QCI was observed in Uzbekistan from 56.4% in 1990 to 37.4% in 2019, 3 moving from rank 146 to rank 201. Liberia had the largest rise in QCI (19.2% in 1990 and 64.5% 4 in 2019), moving from rank 202 in 1990 to rank 104 in 2019. Figure 3 illustrates changes in the 5 top 30 countries with the highest QCI scores from 1990 to 2019. On the other hand, Guyana, Haiti, 6 Burkina Faso, Uzbekistan, and Russian Federation had the lowest age-standardized QCI scores for 7 8 both sexes with 28.34%, 29.4%, 35.3%, 37.4%, and 41.2%, respectively in 2019. 9 According to the WHO classification of world regions, Western Pacific Region (76.6%) had the

10 highest age-standardized QCI score, followed by the Region of the Americas (75.9%) and the

11 European Region (73.3%). Whereas, Eastern Mediterranean Region (63.8%) and African Region

12 (65.3%) had the lowest QCI scores.

Between the 21 GBD regions, high–income North America (82.0%), followed by high–income Asia Pacific (81.1%), had the highest QCI scores while Eastern Europe (43.3%) had the lowest for both genders (Supplementary material online, S4). Supplementary material online, S5 and S6 illustrate the distribution of QCI in different countries classified according to the 21 GBD regions. From 1990 to 2019, the age-standardized QCI score increased in 112 (54.9%) countries by 0.45% to 233.8%. Liberia and Bolivia experienced the greatest improvement by a rise of 236.8% and 234.5%, respectively. Conversely, in 92 (45.1%) countries, the QCI score fell in 2019 versus 1990.

1 Guyana, Uzbekistan, and Russian Federation had the largest decline in QCI scores (34.9%, 33.7%,

2 and 29.8%, respectively).

The QCI score in High SDI (79.3%) countries was higher than global and countries in other SDI
levels, including middle (72.6%), high-middle (72.0%), low-middle (60.4%), and low SDI
(58.9%).

#### 6 Age disparity in QCI

Globally, QCI fluctuated over the lifetime, rising during the first year of life (with 90.2% in 1-4
versus 83.2% in under 1) and remaining fairly stable during childhood and adolescence (1-19 years
old). During early adulthood (20-29 years old), QCI decreased, reaching a nadir of 74.5% in the
25-29 age group. During the 30-49 age groups, QCI climbed to 91.29% at the 45-49 age group.
After leveling off until the 60-64 age group, it gradually dropped to its lowest point (71.7%) at the
95+ age group.

Overall, high SDI countries had higher QCI scores than global and other SDI levels in all age groups. Conversely, low SDI countries had a lower QCI score versus the global score in all age groups. Notably, middle SDI and high-middle SDI countries had more convergence with the global trend than other countries. Except for low SDI countries, in all categories, the highest QCI score was observed in the 1-4 years old age group while the 95+ age group had the lowest QCI scores. In low SDI countries, the 15-19 age group had the highest QCI, and at the 25-29, 55-59, and 70-74 age groups, the QCI reached a nadir. Moreover, the gap between the global trend and high SDI

1 countries was more significant in age groups younger than 44 years of age than older ages.

2 However, in low SDI countries, the gap with the global trend was more considerable in age groups

3 between 50-74 years old compared to younger ages (Figure 4).

#### 4 Gender disparity ratio

- 5 Globally, age-standardized GDR was 1.0 suggesting no considerable disparity in the quality of
- 6 care males and females receive. In different age groups, GDR ranged from 0.8 (70-74 years) to 1.1
- 7 (20-24 years) worldwide. Figure 2b depicts the global distribution of age-standardized GDR.
- 8 In 84 (41.2%) countries, the GDR equaled to 1, suggesting no disparity. While in most countries
- 9 (116 (56.9%)), the GDR was larger than 1, indicating a better QoC in females. Only Tokelau,
- 10 Afghanistan, Bolivia, and Qatar had a GDR lower than 1, equal to 0.9. Low SDI countries had the
- 11 highest GDR (1.2), while middle and high SDI countries had a GDR of 1.0.

# 12 **Discussion**

This is the first study evaluating QoC in endocarditis on a global scale. The age-standardized incidence, prevalence, mortality, and burden (DALY, YLD, and YLL) rates of endocarditis did not significantly change from 1990 to 2019. However, the estimated age-standardized deaths and DALYs decreased from 1990 in low-income countries, potentially as a result of the increased access to antibiotics. Nations with better sociodemographic status, such as high–income North America and Asia Pacific, had higher QCI scores compared to low-income nations. In most

1 countries, women had higher QCI scores; nevertheless, we did not detect gender disparity in QoC

2 of endocarditis globally.

In line with our report, the standardized incidence rate of IE was stable from 1998 to 2013 in two 3 states of the US<sup>19</sup>. Conversely, several investigations found a significant rise in the IE incidence 4 rate in different countries <sup>20-22</sup>. We estimated that the endocarditis incidence rate was higher in 5 6 elderly groups than in the young, with a significantly increased incidence rate in the elderly in 2019 versus 1990. Comparably, in the Danish population, the increased incidence rate was only 7 observed in elderly patients <sup>23</sup>. Furthermore, several studies confirmed a significantly higher mean 8 age in IE patients compared to the past <sup>22, 23</sup>. Therefore, prolonged overall life expectancy can be 9 one of the explanations for the incidence rate rise in all ages. Moreover, we found a higher age-10 standardized incidence rate in men from 2007 to 2016. Similarly, other investigations reported 11 increased male predominance in the 2000s<sup>23, 24</sup>. 12

We estimated that high-income counties had higher incidence and prevalence rates than low-13 income ones. While rheumatic heart disease may be a major predisposing factor for IE in low-14 income regions, its incidence has significantly dropped in high-income nations <sup>25, 26</sup>. However, 15 increasing frequency of prosthetic valve replacement, implantation of indwelling cardiac devices 16 and intravenous catheters, hemodialysis, diabetes, immunosuppression, and intravenous drug use 17 in high-income countries account for the growing incidence rate <sup>1, 20, 27</sup>. Notably, IE due to 18 healthcare-associated causes was more common in recent years <sup>19, 28</sup>, and the occurrence of IE on 19 prosthetic valves, in contrast to native valves, was increased <sup>19, 24</sup>. Lastly, Increased survival of 20

patients with congenital heart disease, who are at a higher risk for developing IE, can be one other underlying reason for the growing incidence rate <sup>27</sup>. In addition to the mentioned shift in the significant risk factors, particularly in high-income regions, the difference can be explained by increased overall life expectancy, prolonged survival of patients with congenital heart disease <sup>29</sup>, and more efficient diagnosis in high-income countries.

We quantified QoC in endocarditis using QCI, estimating an age-standardized global QCI score 6 of 73.64% in 2019. Previous investigations of QoC in endocarditis have shown poor adherence to 7 clinical guidelines <sup>6, 30</sup>. Overall, high-income countries had higher QCI. The top 30 countries with 8 9 the highest QCI score in 2019 were classified as high-income except for three upper-middleincome countries (China, Thailand, and Tonga). Previous studies showed that cardiovascular 10 diseases have higher mortality and morbidity in middle-income countries <sup>31</sup>. Nevertheless, our 11 study provides more focused insights on endocarditis specifically. Lower QCI in countries with 12 limited resources can stem from several reasons, such as delayed hospital admission, failure of 13 organism identification resulting in more frequent administration of empirical antibiotic therapy, 14 and lack of therapeutic drug monitoring. Moreover, valve surgeries, which may improve survival 15 in complicated cases, were more commonly performed in upper-middle-income countries <sup>32</sup>. 16 Higher rates of device-associated infections despite similar device utilization frequency on an 17 international scale compared to the US is another example of geographical disparity, which can be 18 due to lack of skilled healthcare providers, insufficient nurse-to-patient ratio, shortage of medical 19

1 supplies or having outdated technology, overloaded hospitals, and failing to fully comply with the

2 guidelines in countries with limited resources  $^{33}$ .

In addition to the guidelines for the management of IE <sup>34</sup>, antibiotic prophylaxis guidelines for IE prevention, which are a matter of debate, may also play a key role in incidence, clinical features, and outcome. Despite the fewer indication for IE antibiotic prophylaxis in the 2007 American Heart Association guideline, we found no considerable change in QCI or mortality globally and in North America before and after 2007. Nevertheless, the impact of the revisions may vary for patients with different risk levels <sup>35</sup>.

We estimated that globally, gender disparity in the QoC received for endocarditis is infinitesimal. 9 However, in most countries, better care was observed in favor of women, which may be explained 10 by more frequent use of health services and preventive care by women <sup>36</sup> and physiological gender 11 differences. Estrogen may reduce the risk of developing IE by its protective role against endothelial 12 damage <sup>37</sup>. On the other hand, aortic and degenerative mitral valve diseases are more common 13 among men <sup>38</sup>. Furthermore, although controversial <sup>39</sup>, several investigations have reported a 14 higher risk of mortality in men due to IE<sup>22</sup>. We reported a higher GDR (favoring women) in the 15 low-SDI than the high-SDI quintile. Improved healthcare services for both genders in the high-16 SDI countries might have compensated for the biological factors driving a higher QCI in women 17 resulting in a lower GDR. On the other hand, in the low-SDI quintile, the potential protective role 18 of gender might have played a more significant role. 19

Investigation of the QoC distribution in different age groups suggested that children under five 1 years of age have the highest QCI while QCI declines during old age. Guidelines with an exclusive 2 focus on this age group <sup>40</sup>, in addition to generally increased attention to the health outcomes, can 3 explain the high QCI in the under-five age group. Nevertheless, in old age, fatal IE is more 4 common, and patients are at higher risk of mortality <sup>28</sup> due to several reasons, such as weakened 5 immune response <sup>41</sup>. Lack of extensive expertise in elderly care and failure to fully adhere to 6 medical treatments can also contribute <sup>11</sup>. Moreover, a fall in QCI in young adulthood can be 7 attributed to an increased proportion of patients with intravenous drug use, congenital heart 8 disease, and human immunodeficiency virus <sup>42</sup>. Staphylococcal infection, an independent risk 9 factor of mortality <sup>28</sup>, was also more common in younger patients <sup>42</sup>. We observed different 10 distribution of QoC in high and low SDI countries, which can be due to different major 11 predisposing factors in these regions, as discussed earlier. 12

Our study faces several limitations. First, the GBD data does not contain ethnicity stratification, 13 while it has been suggested that race can be a determining factor in QoC in IE <sup>43</sup>. Second, GBD 14 defines endocarditis under diagnostic codes of both infective and non-infective endocarditis. 15 However, the impact of non-infective endocarditis is minimal as it is usually diagnosed in 16 autopsies and can account for only up to 3.7% of deaths caused by endocarditis <sup>44</sup>. Third, we could 17 not differentiate endocarditis QoC according to different microbial agents since microbial 18 etiologies are not stated in the GBD dataset. Fourth, we used the GBD data to investigate the 19 performance of OCI in assessing OoC in endocarditis. To date, this widely accepted data provides 20

the most comprehensive measurement of epidemiological features of diseases. Nevertheless, the 1 lack of sufficient data sources in the GBD study in some regions may have adversely affected the 2 accuracy of the primary indices used in the calculation of QCI. For instance, for Thailand, where 3 had the highest QCI in 2019, no data sources were identified by the GBD study <sup>45</sup>, and the estimates 4 were all model-driven. Although real-world investigations have shown reduced in-hospital 5 mortality from IE in this region <sup>46</sup>, to improve the accuracy of the estimates more primary data 6 sources should be included in the next iterations of the GBD study. Moreover, limitation of 7 statistical and computational resources hindered calculation of the uncertainty interval for QCI in 8 this study. Lastly, the QCI metric is confined to the specific cause for which it is calculated, and it 9 cannot be compared among different causes. Despite these limitations, this is the first assessment 10 of the endocarditis quality of care globally, shedding light on the current trends and highlighting 11 gaps for future investigations and improving healthcare policies. 12

Given the evolving trend in etiology of endocarditis, shift in patient mix and increasing antibiotic resistance of microbial agents, strategies should be adopted to enable timely diagnosis in high-risk populations through procurement of advanced laboratory and imaging modalities, particularly in Eastern Mediterranean and African Regions. Early surgical interventions, which have shown a significant role in improving prognosis <sup>47, 48</sup>, should also be promoted in these regions. Initiatives of multi-disciplinary management can also enhance QoC. There are scant studies on QoC of endocarditis, almost all of which have been conducted in high-income countries. Thus, further

1 investigations incorporating assessment of adherence to the guidelines and their impact on patient

2 outcomes are needed.

To conclude, the incidence rate of endocarditis is rising, and no improvement in mortality or burden has been achieved despite medical advances. Assessment of QoC using the novel QCI metric revealed that better endocarditis quality of care is observed in countries with higher socioeconomic status. Further investigations at national and sub-national levels are required for analyzing endocarditis quality of care.

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# 14 Figure legends

Figure 1. Title: Global epidemiology of endocarditis; Legend: a) number of incident endocarditis cases and the age-standardized incidence rate, (b), number of prevalent endocarditis cases and the age-standardized prevalence rate, (c) number of deaths caused by endocarditis and the agestandardized mortality rate

1 Figure 2. Title: Global distribution of QCI and GDR of endocarditis in 2019; Legend: (a) age-

- 2 standardized quality of care index (QCI) for endocarditis and (b) age-standardized gender disparity
- 3 ratio (GDR) of endocarditis QCI, 2019
- 4 Figure 3. Title: The top thirty countries with the highest age-standardized QCI for endocarditis in
- 5 1990 and 2019; Legend: Abbreviations: AND: Andorra, AUS: Australia, AUT: Austria, BEL:
- 6 Belgium, CAN: Canada, CHE: Switzerland, CHL: Chile, CHN: China, DEU: Germany, DNK:
- 7 Denmark, ESP: Spain, FIN: Finland, FRA: France, GBR: United Kingdom, GRC: Greece, GRL:
- 8 Greenland, IRL: Ireland, ISL: Iceland, ITA: Italy, JPN: Japan, KOR: Republic of Korea, LUX:
- 9 Luxembourg, MCO: Monaco, MLT: Malta, NLD: the Netherlands, NOR: Norway, NZL: New
- 10 Zealand, PRT: Portugal, QAT: Qatar, SMR: San Marino, SWE: Sweden, THA: Thailand, TON:
- 11 Tonga, TWN: Taiwan (Province of China), URY: Uruguay, USA: United States of America

Figure 4. Title: Age trend of QCI for endocarditis at the global level and locations with different
SDI, 2019