

Understanding pediatric surgical needs in North Korea: a modeling analysis

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ABSTRACT

Background Sixty-five percent of children worldwide lack access to surgical care, the majority of whom live in low-income and middle-income countries (LMICs). Developing surgical infrastructure requires information on surgical need; however, this information is often limited in LMICs. North Korea (Democratic People's Republic of Korea, DPRK) has a low amount of publicly available data. Here, we analyzed available modeled data to understand the causes of pediatric deaths due to conditions treatable with surgery in DPRK.

Methods We used World Bank data and models from the Institute for Health Metrics and Evaluation to identify causes of pediatric deaths affecting pediatric patients (age <20 years). We compared mortality of disease between DPRK and countries with similar economic status.

Results Between 1990 and 2019, the number of overall pediatric deaths has decreased. In 2019, 32.2% of all pediatric deaths in DPRK were caused by surgical conditions. The leading categories of surgical conditions were injuries (53.9%), congenital conditions (34.2%), tumors (8.8%), and abdominal conditions (3.2%). DPRK has a lower relative rate of pediatric deaths compared with other LMICs with similar gross domestic product per capita. However, it has a higher relative rate of pediatric deaths due to conditions requiring treatment with surgery. Transport injuries contribute significantly to the high rate of pediatric deaths in DPRK.

Conclusions Although DPRK may be allocating overall resources toward pediatric healthcare more efficiently than economic peers, DPRK may benefit from improvement in pediatric surgical capacity. Improved availability of data and close international collaboration could be potential solutions to bridge this gap.

INTRODUCTION

Every child has the right to a full and healthy life, as stated by the WHO's Convention on the Rights of the Child.¹ Despite widespread efforts to improve the health of children globally, pediatric surgical conditions remain overlooked. Worldwide, an estimated 1.7 billion children and adolescents, comprising 65% of all children and adolescents, lack access to care for surgical conditions, which are defined as conditions that require 'the expertise of a surgically trained provider'.² 89.5% of children and adolescents live in low-income and middle-income countries (LMICs), and

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ North Korea (Democratic People's Republic of Korea, DPRK) has a notable low amount of publicly available primary data on its population of 24 million individuals.
- ⇒ DPRK has a higher burden of non-communicable diseases and child malnutrition than the global average; little is known about pediatric surgical conditions.

WHAT THIS STUDY ADDS

- ⇒ Although DPRK has a lower relative rate of pediatric deaths compared with other low-income and middle-income countries with similar gross domestic product (GDP) per capita, it has a higher relative rate of pediatric deaths due to surgical conditions. In addition, the proportion of pediatric deaths in DPRK caused by surgical conditions has increased steadily, now constituting one-third of all pediatric deaths. The majority of pediatric deaths due to surgical conditions are due to transport injuries. Congenital conditions, tumors, and abdominal conditions also contributed to a large proportion of pediatric deaths. In 2019, 209 005.2 disability-adjusted life years were lost due to surgical conditions in DPRK, amounting to US\$134.4 million loss of the GDP.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ The rising proportion of surgical causes of pediatric deaths in DPRK suggests that it is important for DPRK to invest in surgical care. Although surgical diseases may represent a great challenge to address, DPRK's record of partnering with international organizations highlights the potential impact of similar partnering for pediatric surgical care. Improvements in care are needed at all levels, especially in the areas of prehospital care and care for advanced surgical diseases such as congenital childhood conditions. Improving availability of data, removing obstacles from sanctions, and building an international coalition to support health initiatives in DPRK will help efforts to expand its district-level pediatric surgical services.

make up an overwhelming majority of the population lacking access to surgical care.

Improving countries' capacity to provide surgical care requires information on the burden of surgical disease; however, this



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information is often limited in LMICs. North Korea (Democratic People's Republic of Korea, DPRK) has a notable low amount of publicly available primary data on its population of 24 million individuals. Obtaining a clear understanding of the burden of disease in the country has been a persistent challenge.^{3–5} Published accounts of North Korean healthcare are limited primarily to experiences of a few individuals who have observed work in Pyongyang, DPRK's capital. In addition, there is a scarcity of peer-reviewed articles published in English by DPRK authors. Healthcare in DPRK is largely estimated using data from international organizations, non-governmental organizations, studies on DPRK refugees, and press reports.

In line with this, there remains a limited amount of data demonstrating the overall prevalence of pediatric surgical disease causing death in DPRK. Here, we seek to fill this knowledge gap by analyzing available modeled data to understand the causes of pediatric deaths due to conditions treatable with surgery in DPRK.

METHODS

We used modeling data from the Institute for Health Metrics and Evaluation (IHME) to identify the most prominent surgical conditions in DPRK.⁶ IHME is regarded as the standard for population disease estimates. Its models use advanced statistical algorithms that control for dozens of health-influencing geopolitical and socioeconomic covariates.⁷

We extracted data on deaths, disability-adjusted life years (DALYs), and incidence of diseases affecting people 0–20 years old between 1990 and 2019. We defined diseases requiring surgery as any disease in the IHME database for which mortality may be reduced by a surgical intervention. As an example, within the category of neoplasms, diseases requiring surgery included 'brain and central nervous system (CNS) cancer' and 'kidney cancer', as both benefit from surgical resection. However, we excluded 'leukemia' and all subcategories because

there is generally little role for surgery in preventing mortality from leukemia. Similarly, within the category of injuries, we included 'fire, heat, and hot substances' as a disease requiring surgery (burn surgery); however, we excluded 'poisonings from carbon monoxide' given the limited role of surgery.

Outcomes included incidence and mortality. Relative death rates were calculated as rate of death normalized by the incidence of disease. We also extracted corresponding IHME data from economic peers and from South Korea to contextualize relative outcomes.

DALYs were used to calculate the total economic impact of these pediatric surgical conditions using methods established by Dalal and Svanström, with value of DALYs lost calculated by multiplying the DALYs lost due to the condition by the country's gross domestic product (GDP) per capita.⁸ All analyses were conducted using Microsoft Excel.

Patient and public involvement

Given that this research was based on publicly available census and modeling data, it was not indicated to involve patients or the public in the design, or conduct, or reporting, or dissemination plans of our research.

RESULTS

We analyzed the total number of pediatric deaths and the proportion of pediatric deaths due to surgical and non-surgical conditions over the last 30 years (figure 1). Overall, the number of pediatric deaths has decreased steadily. There was a sudden increase in deaths due to non-surgical conditions in 1994, coinciding with the 1994–1998 North Korean famine.^{9–11} After the famine, between 2001 and 2005, the death rate decreased rapidly. Of note, as a result of a gradual reduction of deaths due to non-surgical conditions, surgical conditions now make up a significant proportion of pediatric deaths.

We then analyzed the main causes of pediatric deaths due to surgical conditions. In 2019, 32.2% of all premature

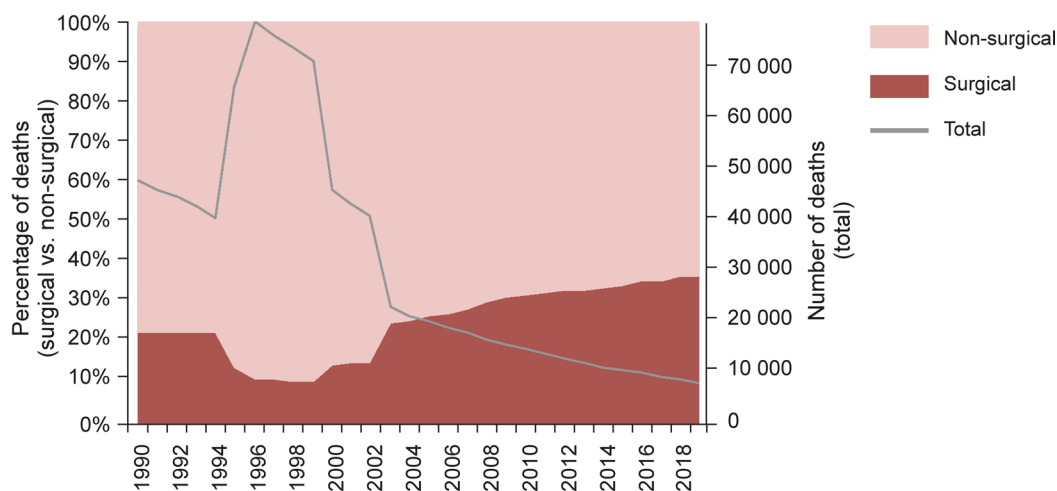


Figure 1 Total number of pediatric deaths and proportion of pediatric deaths due to surgical and non-surgical conditions, 1990–2019.

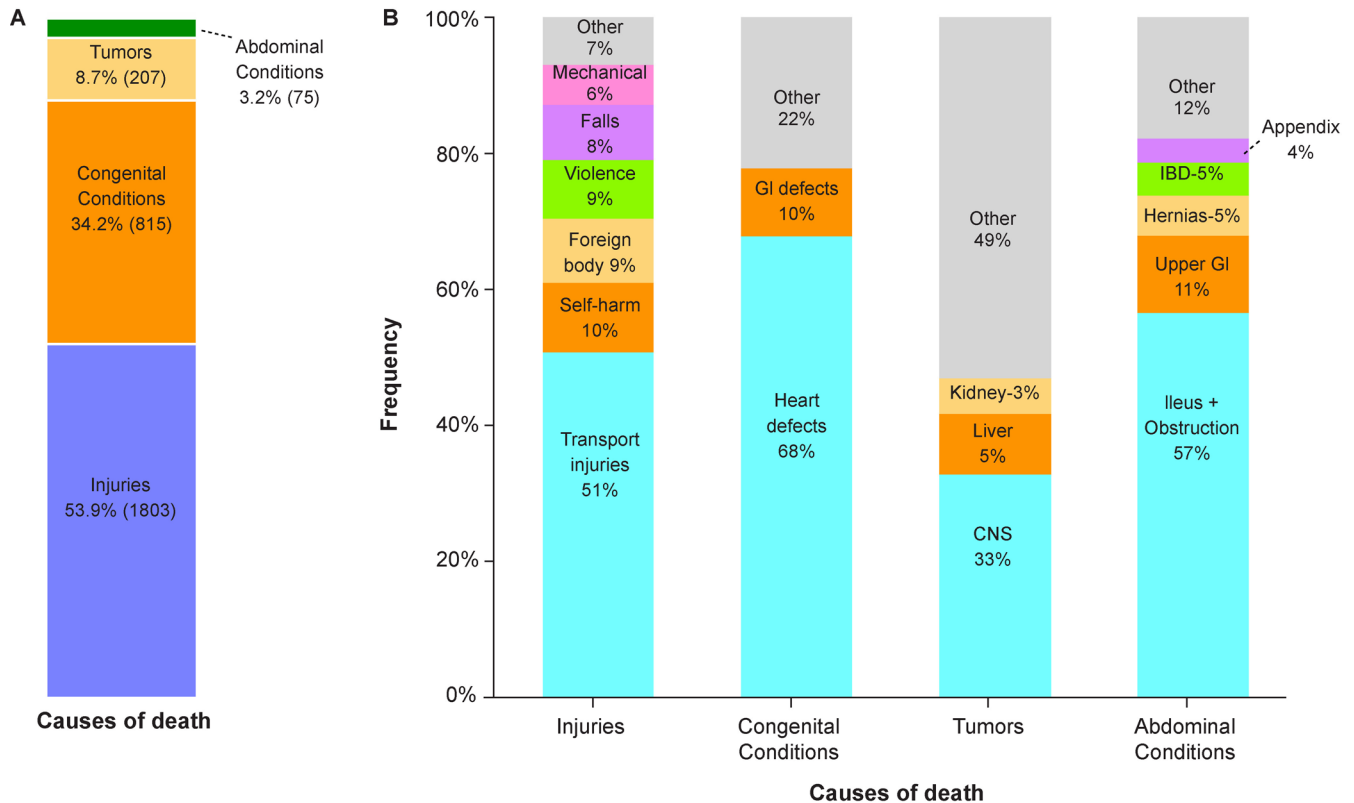


Figure 2 Causes of pediatric deaths: (A) general categories; (B) causes of death within the four general categories. CNS, central nervous system; GI, gastrointestinal.

pediatric (0–20 years) deaths in DPRK were caused by surgical conditions (figure 2A). In descending order, the leading four causes were injuries (53.9%), congenital conditions (34.2%), tumors (8.8%), and abdominal conditions (3.2%). We ranked specific pediatric diagnoses within each category (figure 2B). For injuries, transport injuries (largely road traffic accidents) were the leading cause of death (51%), while self-harm was the second leading cause (10%). For congenital conditions, the leading cause of death was congenital heart anomalies (68%) with gastrointestinal (GI) defects second (10%). For tumors, brain and nervous system cancers ranked first (33%), followed by liver cancer as the second most common cause of death (5%). Among abdominal conditions, paralytic ileus and intestinal obstruction was the leading cause of death (57%), and upper GI conditions caused the second most deaths (11%).

To assess how well DPRK manages pediatric surgical conditions in relation to other countries, we analyzed the rate of death against the incidence of all causes of pediatric deaths, as well as surgical causes of pediatric deaths. DPRK's rates were compared with those of four other LMICs with GDP per capita similar to that of DPRK (Ethiopia, Rwanda, Sierra Leone, and Uganda), as well as those of South Korea (Republic of Korea, ROK) (online supplemental table 1).

DPRK had a lower absolute rate of death per 100 000 children compared with the other four LMICs (online supplemental figure 1). However, its incidence of the

causes of death was also lower. To learn more about the impact of pediatric healthcare in DPRK, we analyzed relative death rates, which we calculated as rate of death normalized by the incidence of disease. When examining all causes of death (both surgical and non-surgical), we found that DPRK had a lower relative death rate in children compared with other LMICs (figure 3A). In contrast, when examining surgical causes, DPRK had a higher relative death rate in children compared with three of the four other LMICs (figure 3B).

We then analyzed the relative death rate of children for each of the four leading surgical causes of death. Compared with other LMICs, DPRK had a lower incidence of transport injuries, the leading cause of death (figure 4A). However, the relative death rate in DPRK was much higher. Similarly, DPRK had a somewhat lower incidence of congenital cardiac defects, but a similar or higher relative death rate compared with the other LMICs (figure 4B). For CNS tumors, DPRK had a similar incidence compared with other LMICs, as well as a similar death rate (figure 4C). In contrast, for ileus and obstruction, DPRK had a similar incidence compared with other LMICs, but a lower relative death rate, though not as low as that of the ROK (figure 4D).

Finally, we estimated the economic impact of untreated pediatric surgical conditions in DPRK by multiplying DPRK's 2019 GDP per capita of 643 with the number of lost DALYs.¹² We made the assumption that with proper pediatric surgical care, the child would grow up healthy

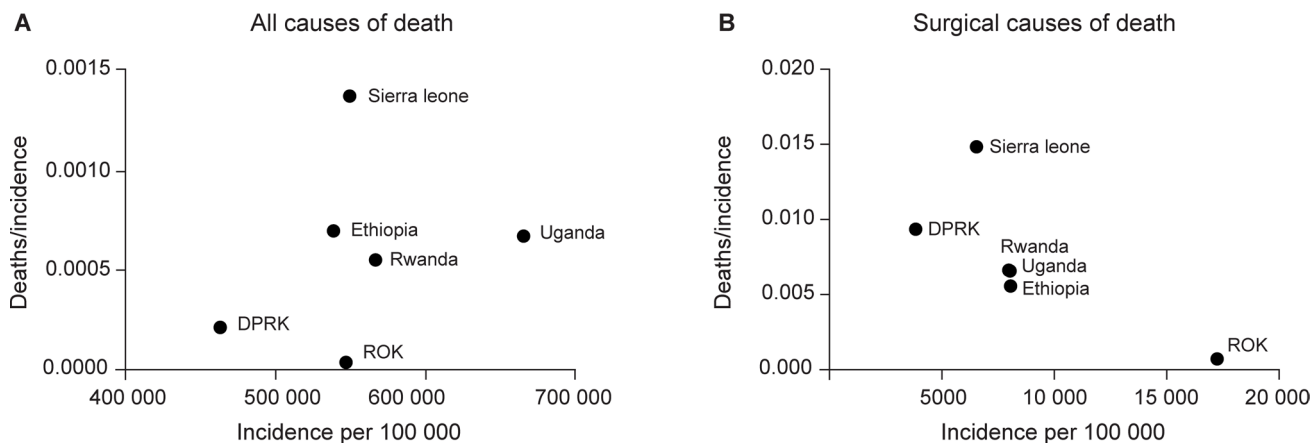


Figure 3 Incidence and rates of death in DPRK and peer countries: (A) all causes of death; (B) surgical causes of death. DPRK, Democratic People's Republic of Korea; ROK, Republic of Korea.

and eventually contribute to the economy. 209 005.2 DALYs were lost due to surgical conditions in 2019, amounting to US\$134.4 million loss of the GDP.

DISCUSSION

Investing in pediatric surgical care prevents deaths and disabilities. Our analysis suggests that, although DPRK has a lower relative rate of pediatric deaths compared with

other LMICs with similar GDP per capita, it has a higher relative rate of pediatric deaths due to surgical conditions. In addition, the proportion of pediatric deaths in DPRK caused by surgical conditions has increased steadily, now constituting one-third of all pediatric deaths. The majority of pediatric deaths due to surgical conditions are due to injuries, followed by congenital conditions, tumors, and abdominal conditions.

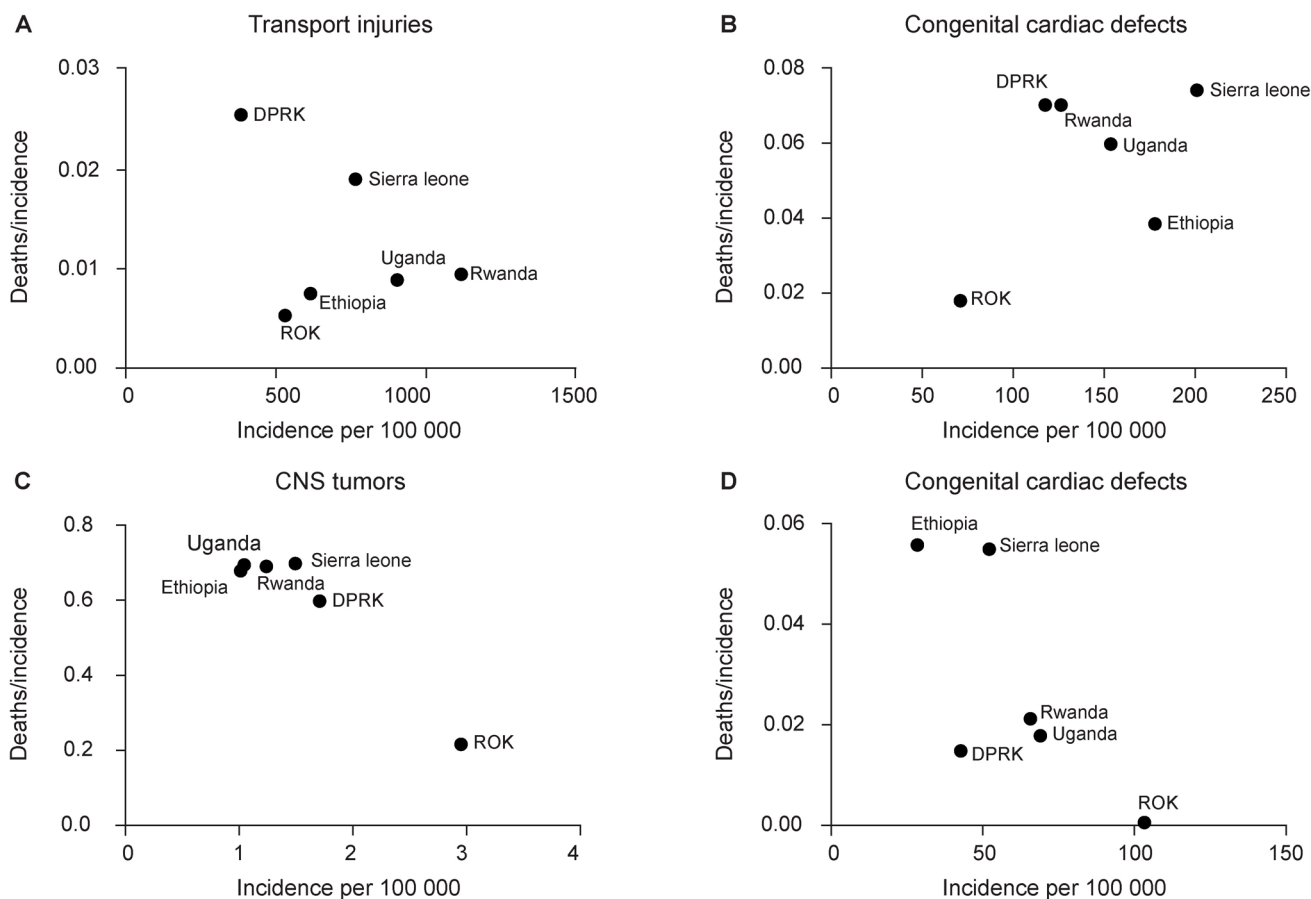


Figure 4 Incidence and rates of death in DPRK and peer countries due to leading causes of death: (A) transport injuries; (B) congenital cardiac defects; (C) CNS tumors; and (D) ileus and obstruction. CNS, central nervous system; DPRK, Democratic People's Republic of Korea; ROK, Republic of Korea.

Injuries are the leading cause of pediatric surgical deaths, causing 53.9% of all pediatric surgical deaths, with transport injuries being the most common (figure 2). In recent years, DPRK has experienced a marked growth in road traffic; however, the country may benefit from a medicalized prehospital transportation system.¹³ In one study, patients who survived transport injuries arrived at medical facilities either by walking, household means of transportation (bicycle, cart pulled by cows), or public transportation. Some patients did not seek hospital care given distance to the hospital. The high relative death rate in DPRK may be due to a combination of lack of prehospital transportation, delayed care, and lack of infrastructure and supplies to support the trauma care delivery. However, these issues are not unique among LMICs, as the other four LMICs also face similar challenges to their systems.^{14–17}

Congenital conditions and tumors, the second (34.2%) and third (8.7%) leading causes of death, represent conditions that may require intensive infrastructure and resources to treat, including surgical specialists and intensive care units. This is indeed the case for congenital cardiac defects and CNS tumors, the leading causes in these two categories. Compared with other LMICs, DPRK had similar or higher relative pediatric death rates due to congenital cardiac defects, as well as similar rates due to CNS tumors. This may suggest that the surgical infrastructure and level of training in these LMICs are limiting factors for these diseases, which lead to death more often than in a high-income country. Interestingly, DPRK had a lower rate of congenital cardiac defects compared with the other LMICs studied, but a higher rate than the ROK. This may be due to differences in environmental exposures such as alcohol, secondhand smoke, or diabetes, which are potentially related to these defects. These differences suggest the global importance of maternal health, maternal nutrition, and intrauterine monitoring.¹⁸

DPRK appears to have a lower death rate of ileus and obstruction compared with other LMICs. This may suggest that DPRK may have adequate resources to manage common surgical conditions that do not require advanced infrastructure, in contrast to congenital conditions and CNS tumors. At the same time, the ROK shows that the death rate from ileus and obstruction can be made exceedingly low with proper surgical care. In the ROK, the relative rate of death from ileus and obstruction is approximately 19-fold lower than that in DPRK—a difference greater than for any other condition analyzed.

Although there are little data regarding the prevalence of surgical diseases in DPRK, other articles have also used creative methods to achieve a better understanding. Two articles performed a review of *Surgery*, the major medical journal in DPRK.^{3,19} These articles identified that trauma was the most commonly discussed surgical condition and that the most commonly mentioned specialties were general and orthopedic surgery. These findings support our finding of a high proportion of injuries. The articles

also found that only 4.4% of papers mentioned the use of CT imaging and 1.8% reported the use of MRI, suggesting limited availability of standard imaging modalities.

The rising proportion of surgical causes of pediatric deaths in DPRK suggests that it is important for DPRK to invest in surgical care. Although there may be a general perception that surgical intervention is unacceptably costly in LMICs, recent economic models demonstrated that implementation of a dedicated pediatric operating room in an LMIC is decidedly cost-effective, with an incremental cost-effectiveness ratio that meets multiple established thresholds.^{20,21} Having a cost-effective way to address pediatric surgical conditions would decrease not only pediatric deaths but also the personal and economic burdens caused by disability, leading to a healthier population and economy.

While LMICs including Ethiopia, Rwanda, Sierra Leone, and Uganda have benefited from investments in pediatric surgical care, DPRK is not known to have made this investment.^{22–25} This may be in part because DPRK's efforts to strengthen surgical care have remained limited due to international sanctions.^{26,27} Despite these sanctions, DPRK is prioritizing strengthening surgical capacity. This was studied by a group examining recent government-written editorials within medical journals in DPRK in an effort to identify the government's priorities.²⁸ Their study demonstrated that the areas of greatest concern included the development of medical science and technology, suggesting the potential for investing resources into growth.

In 2015, DPRK delegation at the 68th World Health Assembly voted for the resolution 'Strengthening of Emergency and Essential Surgical Care and Anesthesia and a Component of Universal Health Coverage.' DPRK then incorporated the resolution recommendations into its 2016–2020 Medium Term Strategic Plan for the Health Sector, including the provision of the 'WHO Emergency Essential Surgical Package at the first referral level'.²⁹ In December of 2019, the ROK Ministry of Unification announced a \$5 million donation to the WHO for the improvement of access to pediatric surgical care for women and children in DPRK.³⁰ A key barrier to successful implementation is the current layers of international sanctions against DPRK. This grant will help assess the feasibility of an international health capacity building project and its requirements, such as viable banking channels to facilitate financial transactions and exemptions from the United Nations Security Council DPRK Sanctions Committee.

Of note, DPRK has shown that international aid can lead to timely improvements in care. One partnership with the WHO and UNICEF increased diphtheria, tetanus, and pertussis vaccine coverage from 37% in 1997 to 96% in 2013.³¹ This partnership may have been one of many factors contributing to the consistent decrease in overall numbers of pediatric deaths in recent years. Thus, although surgical diseases may represent a great challenge to address, DPRK's record of partnering with

international organizations highlights the potential impact of similar partnering for pediatric surgical care.

Conclusion

DPRK's modeled statistics on pediatric health suggest that, although the country may be allocating its resources toward pediatric healthcare more efficiently than its economic peers, there may be a gap in DPRK's ability to provide pediatric surgical care. Improvements in care are needed at all levels, especially in the areas of prehospital care and care for advanced surgical diseases such as congenital childhood conditions. Improving availability of data, removing obstacles from sanctions, and building an international coalition to support health initiatives in DPRK will help efforts to expand its district-level pediatric surgical services.

Limitations

Although primary data would best inform public health decisions, the lack of access in DPRK limits this study along with many others. The IHME and the United Nations World Population Prospects base their estimates on decade-old health data. The United Nations World Population Prospects 2019 Report, for example, relies on DPRK's 2000–2009 population census.^{32 33} Notably, the IHME houses only 133 direct data sources from DPRK, which is one of the lowest of all countries (in comparison, the four peer countries have between 331 and 1146 direct data sources). Accordingly, the IHME model uses significant assumptions and extrapolations. In addition, data on surgical conditions may be either underestimated or overestimated because databases do not collect metadata on whether each condition is a surgical condition.

Direct sampling at the early stages of upcoming pediatric health projects will better guide resources intended to improve people's lives. Many tools have been developed for measuring conditions that may require surgical intervention, including the Surgeons Overseas Assessment of Surgical Need tool.³⁴ These tools would be useful for future studies and would help meet some of the limitations of this current study. Although primary data are available from peer countries as a comparison, we chose to use IHME data to keep data sources consistent. Comparisons between DPRK and peer countries are available only as a reference, as many potential confounders are possible, including international aide.

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Contributors PJH analyzed and interpreted the data. PJH and SY wrote the article with edits from KBP. KBP, the guarantor, conceived the idea for the manuscript and supervised the work.

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Data availability statement Data are available in a public, open access repository.

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