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Does reducing out-of-pocket costs for children’s surgical care protect families from poverty in Somaliland? A cross-sectional, national, economic evaluation modelling study

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ABSTRACT

Objectives An estimated 1.7 billion children around the world do not have access to safe, affordable and timely surgical care, with the financing through out-of-pocket (OOP) expenses being one of the main barriers to care. Our study modelled the impact of reducing OOP costs related to surgical care for children in Somaliland on the risk of catastrophic expenditures and impoverishment.

Design and setting This cross-sectional nationwide economic evaluation modelled several different approaches to reduction of paediatric OOP surgical costs in Somaliland.

Participants and outcome measures A surgical record review of all procedures on children up to 15 years old was conducted at 15 surgically capable hospitals. We modelled two rates of OOP cost reduction (reduction of OOP proportion from 70% to 50% and from 70% to 30% reduction in OOP costs) across five wealth quintiles (poorest, poor, neutral, rich, richest) and two geographical areas (urban and rural). The outcome measures of the study are catastrophic expenditures and risk of impoverishment due to surgery. We followed the Consolidated Health Economic Evaluation Reporting Standards.

Results We found that the risk of catastrophic and impoverishing expenditures related to OOP expenditures for paediatric surgery is high across Somaliland, but most notable in the rural areas and among the poorest quintiles. Reducing OOP expenses for surgical care to 30% would protect families in the richest wealth quintiles while minimally affecting the risk of catastrophic expenditure and impoverishment for those in the lowest wealth quintiles, particularly those in rural areas.

Conclusion Our models suggest that the poorest communities in Somaliland lack protection against the risk of catastrophic health expenditure and impoverishment, even if OOP payments are reduced to 30% of surgical costs. A comprehensive financial protection in addition to reduction of OOP costs is required to prevent risk of impoverishment in these communities.

INTRODUCTION

Health financing is an intrinsic part and core function of universal health coverage. Health financing significantly influences both the extent to which the population can access health services, as well as the extent to which they face financial hardship in the process. In a strong health financing system, there are no financial barriers to access; and out-of-pocket (OOP) health spending is not a source of financial hardship. When contributing to health financing, OOP health spending should not be carried disproportionately by the poor and not at all by the poorest. In general, health systems that require lower OOP payments for healthcare offer better protection to the poor against catastrophic spending. Any spending of OOP on the poor represents a major challenge to achieve the global goal of ending poverty in all its forms everywhere. However, the burden of OOP health spending is common and...
disproportionately high in low/middle-income countries (LMICs), and especially in rural areas.\textsuperscript{3–8} A study from 89 countries suggested that worldwide, 150 million people suffer financial catastrophes every year due to OOP medical costs, with the highest severity among LMICs.\textsuperscript{3} In this context, poor households are left with the hard choice of seeking care risking impoverishment, or not seeking care at all.\textsuperscript{10}

Given that up to 50% of the population in LMICs are children and many of these children have surgical conditions,\textsuperscript{11–15} the financial impact of surgical care for children on families and communities has enormous global consequences.\textsuperscript{16} Without investing in surgical and anaesthesia care in LMICs, approximately $12 trillion will be lost to the global economy between 2015 and 2030 due to untreated surgical conditions.\textsuperscript{17} In addition to these macroeconomic impacts, surgical care affects individual families and communities at a microeconomic level. Approximately half the world’s population is at risk of catastrophic expenditures for surgical care if they do not have comprehensive financial risk protection.\textsuperscript{18} Although many studies have evaluated catastrophic expenditures and impoverishment, none have specifically assessed the impact of strategies to reduce OOP costs on families.

Our previous work has found a large burden of surgical conditions for children in Somaliland, with a significant surgical backlog and limited workforce and infrastructure capacity, especially in rural areas.\textsuperscript{15 19–23} Furthermore, the presence of a surgical condition itself is a risk factor for families to descend into poverty.\textsuperscript{24} We also identified sub-Saharan Africa as the region with the highest risk of financial hardship compared with the rest of the world. Building on this research, the objective of this current study was to model the impact of reducing OOP costs for surgical care for children in Somaliland on the risk of catastrophic expenditures and impoverishment across wealth quintiles as well as between rural and urban areas. In doing so, these analyses could provide guidance on financial risk protection mechanisms within universal health programmes for Somaliland and other LMICs.

**METHODS**

Our goal was to estimate the impact of reducing OOP costs for surgical care in children across Somaliland by modelling the risk of catastrophic expenditures and impoverishment under various scenarios. We modelled several different approaches to reduction of OOP costs, including two rates of OOP cost reduction, chosen as intermediate and aspirational goals of reducing costs, comparison across five wealth quintiles (poorest, poor, neutral, rich, richest) and differences between geographical areas (urban and rural). This study follows the Consolidated Health Economic Evaluation Reporting Standards.

**Setting**

This study took place in Somaliland, a country in the Horn of Africa which, although not recognised as an independent state, has achieved relative stability since separation from Somalia in 1991.\textsuperscript{25} Out of the total population of 4 million people, approximately 50% are children under the age of 16.\textsuperscript{20 26} The infant mortality rate is one of the highest in the world, with approximately 90 deaths/1000 live births compared with 41 deaths/1000 live births in neighbouring Ethiopia and 6/1000 live births in the USA.\textsuperscript{25}

Somaliland is rebuilding its healthcare and public health infrastructure after the devastating 1990 civil war where nearly all of the hospitals and clinics were damaged. The public health system is comprised of primary health centres, referral health centres, regional hospitals and a national referral hospital. Private specialty hospitals include several tuberculosis hospitals, a female fistula hospital and a mental health hospital. Somaliland has 16 surgically capable hospitals, defined as the presence of a hospital operating room, 87 medical centres for health and 165 health posts.\textsuperscript{24} In addition, the private sector makes up about 60% of Somaliland’s healthcare market and provides a substantial proportion of health services in the country. Our previous work found that most hospitals for children’s surgical care are in the urban capital of Hargeisa and, thus, provide the highest number of surgical cases for children in the country.

**Data input parameters**

Data input parameters to calculate catastrophic expenditures and rates of impoverishment are described in detail below.

**Rurality, population estimates, wealth quintile estimates and Gini coefficient**

The overall gross domestic product (GDP) per capita is $682 in Somaliland.\textsuperscript{27} Poverty rates, defined as those living below $3.10 per day,\textsuperscript{28} in rural areas are higher than in urban areas (37% vs 30%, respectively). The rate of extreme poverty, defined as those living below $1.90 per day,\textsuperscript{29} is high in Somaliland, with 21% of the population living under extreme poverty compared with 9.5% in urban areas.

We calculated GDP per capita by region and wealth quintile (see online supplemental material for detailed information). In summary, we calculated wealth quintile information in the following steps. First, for each country’s Gini, we assumed a gamma distribution and selected the correct shape given the Gini. Then, 25 income distributions were created for each candidate GDP per capita, along with the mean poverty head counts and poverty gap. The GDP per capita which approximated the target poverty head count was selected, and we checked that is also predicted an appropriate gap index. We then found the quintiles for each gamma distribution parameterised with the GDP per capita selected in the last step for 0.10, 0.30, 0.50, 0.70 and 0.90, which were used as the midpoint values for each quintile. Lastly, we reparameterised a gamma distribution with the mean income at each
value. The parameterisation of the distribution, given any GDPpc and Gini, is given in the first equation:

\[
E(CE) = \frac{N}{\Gamma(\alpha)\beta^\alpha} \int_0^{\infty} \frac{\alpha^\alpha}{\beta^\alpha} p(y)^{\alpha-1} e^{-\frac{y}{\beta}} dy
\]

\[
E(CE) = \frac{Q}{\Gamma(\alpha)\beta^\alpha} \sum_{q \in Q} \sum_{p \in P_q} \int_0^{\infty} \frac{\alpha^\alpha}{\beta^\alpha} p(y)^{\alpha-1} e^{-\frac{y}{\beta}} dy
\]

Note that since we are calculating the incidence of catastrophic expenditures, the \( p(y) \), or the probability of getting surgery as a function of income, drops out.

**Calculation of direct costs**

Data on actual costs of individual surgical procedures for children in LMICs are scarce in the literature, and vary widely by setting and type of hospital (for-profit, nonprofit, government).\(^{29,30}\) In the absence of paediatric surgery-specific cost data, we used proxy measures of costs related to surgical procedures in adults for a range of countries from Gibbons et al.\(^{31}\) as well as data from the Lancet Commission on Global Surgery for a caesarean section ($179 for low-income countries and $219 for high-income countries).\(^{30}\) We used the midpoint unit cost between low-income countries and middle-income countries as our baseline estimate of $200 per paediatric surgical procedure.\(^{30}\)

**OOP costs**

We estimated OOP costs related to a paediatric surgical procedure in Somaliland based on our previous research.\(^{32}\) In brief, a surgical record review of all procedures on children between the ages of 0 and 15 years was conducted at 15 surgically capable hospitals.\(^{32}\) We used the Lancet Commission on Global Surgery’s Surgical Assessment Tool-Hospital Walkthrough and the Global Initiative for Children’s Surgery’s Global Assessment of Pediatric Surgery to create a de novo single-page hospital assessment tool to assess surgical infrastructure and capacity.\(^{32,33}\)

Surveys were completed by several stakeholders from each hospital, including a surgeon or an administrator (preferably the medical director). Regarding financial indicators, we asked survey respondents to estimate the average OOP expenditures expressed as a percentage for overall direct costs for a paediatric surgical procedure at their hospital.\(^{32}\) We used this average percentage of 70% to quantify the baseline OOP costs for each region by multiplying the percentage by the direct medical costs (see online supplemental material for detailed information).

**Outcome definitions: risk of catastrophic expenditures and impoverishment**

Our two main outcomes included catastrophic expenditures and risk of impoverishment due to surgery.\(^{34}\) Catastrophic expenditure was defined as OOP expense of greater than 10% of the patient’s GDP based on WHO standards.\(^{35}\) To calculate catastrophic expenditure, we used the following formula, where \( c \) represents the OOP costs of the procedure, \( i \) is the chosen threshold level and \( y \) is the GDP per capita.

\[
c > = ty
\]

Impoverishing expenditure is defined as being pushed into poverty or being pushed further into poverty by OOP payments, defined as:

\[
y - c < T
\]

Where \( T \) corresponds to the impoverishment thresholds. For the current study, we used three values for \( T \): the national poverty line ($219 per annum\(^{36,37}\)), the WHO poverty line (US$3.10 per day) and the WHO extreme poverty line (US$1.90 per day).\(^{38}\) The risk of impoverishment for each hospital and region was estimated by subtracting the OOP expenses from the yearly income.

**Data analysis**

We used the catastrophic and impoverishing expenditure tool developed by Shrime et al.\(^{34}\) to analyse the population-level risk of catastrophic health expenditure and impoverishment due to direct medical costs by region, rurality and between wealth quintiles. We evaluated the impact of reducing OOP expenditures to 50% and 30% by wealth quintile and rurality. We estimated the per cent of the population protected from the risk of catastrophic health expenditure and impoverishment if OOP costs were reduced to 30%, by wealth quintile and rurality, according to population estimates from the latest Somaliland Demographic and Health Surveys and the equity tool.\(^{39}\) Descriptive statistics were used to analyse the data collected and compared by wealth quintile and region. We analysed the data using SAS software V.9.4, R V.3.0 (www.r-project.org) and Microsoft Excel V.2018 (Redmond, Washington, USA).

**Sensitivity analyses**

To test the robustness of the cost estimate, we ran sensitivity analyses using low-end and high-end estimates of $130 and $608 per unit surgical cost, respectively, based on estimates from our previous systematic review.\(^{40}\) For the sensitivity analyses, we used the lower end for orthopaedic conditions ($130 per unit surgical cost) and the higher end for various neurosurgical conditions ($608 per unit surgical cost). We then reran the analyses based on the low-end and high-end costs by reducing those costs to 50% and 30% OOP.

**Patient and public involvement**

No patients or members of the public were involved in the design, choice of outcome measure or recruitment in the study.

**RESULTS**

We found that the risk of catastrophic expenditures due to a surgical procedure in children in Somaliland at baseline OOP payments of 70% was very high (98.4%) and did not differ significantly by urban or rural areas (97.8%...
and 95.3%, respectively) (Table 1). If OOP costs were reduced to 50%, the overall absolute risk of catastrophic expenditure would be reduced by 10.5%, with the most notable reduction in urban areas (14.2%) compared with rural areas (9.9%). If OOP costs were reduced further to 30%, the overall risks of catastrophic expenditures would be reduced by 52.3%, with greater benefit occurring in urban areas (62.1%) than rural areas (36.2%).

According to the poverty line of $1.90 per day, we found similar trends with overall risk of impoverishing expense being pushed below this line due a paediatric surgical expense being high throughout the country at 47.2% but the highest in rural areas than urban areas (61.0% vs 34.5%, respectively). According to the poverty line of $3.10 per day, 83.9% of families of children needing surgical care are at risk of impoverishment. Although reducing OOP reduced the risk of impoverishment according to poverty, the reduction was marginal at both the 50% and 30% reduction levels for rural areas (2.3–4.7 risk reduction, respectively) compared with urban areas (4.8–10.1 risk reduction, respectively).

Looking across wealth quintiles, persons living in the richest quintiles benefited the most from reducing OOP costs, particularly for people living in urban areas (figure 1). Among those at risk of catastrophic expenditures, reducing OOP to 30% reduced the risk of catastrophic expenditure in all wealth quintiles in urban areas except for the poorest quintile. Among persons in rural areas, the risk of catastrophic expenditures was barely reduced for those in the poorest quintile and only marginally reduced for the poor quintile. Similar trends were observed when looking at the risk of impoverishment among persons living in poverty across rurality and quintile.

Accounting for population density within each region and quintile, the greatest benefit of reducing OOP costs to 30% occurred among the top three wealth quintiles (figure 2). If OOP costs were reduced to 30%, 56.6% of the population in the richest wealth quintile would be protected, while only 13.6% of the population in the poorest wealth quintile would be protected from catastrophic health expenditures. Among persons living in poverty, reducing OOP costs to 30% would protect between 7.8% and 12.0% in the poorest quintiles and 10.9% in the middle quintile. Among persons living in extreme poverty, less than 1% of persons living in the poorest quintile would be protected from the risk of impoverishment even when OOP costs were reduced to 30%.

### Table 1 Risk of catastrophic health expenditure and impoverishment due to paediatric surgery in Somaliland

<table>
<thead>
<tr>
<th></th>
<th>Catastrophic expenditure</th>
<th>Impoverishment $1.90 (extreme poverty)</th>
<th>Impoverishment $3.10 (poverty)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% risk (CI)</td>
<td>% reduction from baseline (CI)</td>
<td>% risk (CI)</td>
<td>% reduction from baseline (CI)</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Baseline ($130)</td>
<td>98.4 (89.7, 100.0)</td>
<td>–</td>
<td>47.2 (29.4, 66.3)</td>
</tr>
<tr>
<td>50% of baseline</td>
<td>87.9 (52.6, 99.8)</td>
<td>10.5 (0.2, 37.1)</td>
<td>40.0 (24.2, 58.3)</td>
</tr>
<tr>
<td>30% of baseline</td>
<td>46.1 (6.2, 91.0)</td>
<td>52.3 (9.0, 83.5)</td>
<td>32.9 (19.2, 50.2)</td>
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<tr>
<td>Urban areas</td>
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<tr>
<td>Baseline ($130)</td>
<td>97.8 (85.4, 100.0)</td>
<td>–</td>
<td>34.5 (18.8, 54.3)</td>
</tr>
<tr>
<td>50% of baseline</td>
<td>83.6 (40.0, 99.7)</td>
<td>14.2 (0.3, 45.4)</td>
<td>27.6 (14.2, 45.3)</td>
</tr>
<tr>
<td>30% of baseline</td>
<td>35.7 (2.3, 86.8)</td>
<td>62.1 (13.2, 83.1)</td>
<td>21.0 (10.5, 36.2)</td>
</tr>
<tr>
<td>Rural areas</td>
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</tr>
<tr>
<td>Baseline ($130)</td>
<td>95.3 (85.4, 99.5)</td>
<td>–</td>
<td>61.0 (50.7, 71.6)</td>
</tr>
<tr>
<td>50% of baseline</td>
<td>85.4 (64.2, 97.4)</td>
<td>9.9 (2.1, 21.2)</td>
<td>56.9 (46.7, 67.3)</td>
</tr>
<tr>
<td>30% of baseline</td>
<td>59.1 (28.7, 86.0)</td>
<td>36.2 (13.5, 56.7)</td>
<td>52.7 (42.8, 63.2)</td>
</tr>
</tbody>
</table>

Yearly income was $642 (overall), $709 (urban) and $575 (rural). Baseline OOP was estimated as 70% of $200 per paediatric surgical procedure.

OOP, out-of-pocket.
By extrapolating our findings to the population of Somaliland, reducing OOP costs to 30% of surgical expenditures would lead to approximately 1.6 million people being protected from catastrophic expenditures, 389,040 living in poverty being protected from impoverishment and 199,460 living in extreme poverty being protected from impoverishment (table 2). However, the greatest benefit is among those in the two richest wealth quintiles for catastrophic expenditures and impoverishment at the $3.10 level in urban areas. Among those in extreme poverty, the greatest impact in terms of absolute numbers occurred among those in the poorest wealth quintiles in urban areas but not rural.

Lowering the price of surgical procedures to the lower end of our sensitivity analyses at $130 reduced the risk of catastrophic expenditure, impoverishment of extreme poverty and impoverishment of poverty, while increasing to the higher end of $608 per surgical procedure increased the risk (table 3). Notably, the risk of catastrophic expenditure was reduced by approximately 20% on the lower end value of $130 in rural and urban areas, with the greatest reduction in urban areas, while increasing to the higher value to $608 increased the risk to nearly 100%. Lowering the price of each surgical procedure to the lower end of $130 also reduced the risk of impoverishment according to both levels of poverty, but

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most notably affected the urban areas more. Lowering the price to $130 reduced the risk of impoverishment according to the extreme poverty level by 20%–50% in all areas. However, the reduction in risk was most notable in the urban areas rather than rural areas where the risk remained above 50%.

**DISCUSSION**

We found that the risk of catastrophic expenditures and impoverishment related to OOP expenditures for surgical care in children across Somaliland is high. In addition, we found that a large majority of the population would be pushed below the poverty lines if surgical care was needed for their child across all areas, but most notably in rural areas among the poorest quintiles. Reducing OOP expenses for surgical care to 30% would protect families in the richest wealth quintiles while minimally affecting the risk of catastrophic expenditure and impoverishment for those in the lowest wealth quintiles, particularly those in rural areas. These findings suggest that the poorest of the poor in the most remote areas remain the least protected, even if OOP costs are substantially reduced.

With a GDP of $682 in 2020 and ranked among poorest countries in the world, it is not surprising that Somaliland struggles to achieve improvements across all quintiles even when OOP expenses are reduced drastically. Our data suggest that 98.4% of households in Somaliland were at risk of experiencing catastrophic expenditure at an OOP health spending baseline of 70%, 87.9% households were at risk of an OOP health spending baseline of 50% and 46.1% households were at risk of an OOP health spending baseline of 30%. Limited literature has focused on evaluating OOP and catastrophic expenditures for surgery in LMICs, and research on paediatric surgery financing is even more scant. Among the existing literature, risk of catastrophic expenditure is often calculated at a baseline of an OOP health spending of 10%, limiting ideal comparisons with our study case. For instance, in Western Uganda, 45.5% of households were at risk of catastrophic expenditure, with higher prevalence in lower-income brackets. Another study from Kampala, the capital of Uganda, 27% of households were at risk of catastrophic expenditure. Similar to many areas of healthcare in LMICs, the rural–urban gaps between the risk of catastrophic expenditures and impoverishment related to surgical care are widespread. In LMICs, the rural–urban gaps in the percentage with OOP health spending of least 25% of household consumption are the widest compared with higher-income countries. We found that the risk in rural areas for catastrophic expenditures and impoverishment related to surgical care for children was higher than urban areas across all wealth quintiles, even if OOP costs were reduced to 30%. In addition, our sensitivity analyses showed that even reducing the cost of surgery plus reducing OOP costs to the lowest 30% would still benefit the richest quintiles in urban areas the most. As an illustrative example, reducing the cost of surgery to the lower end of the sensitivity analysis is equivalent to the price of common orthopaedic conditions, $130. By reducing the OOP expenditure to the lowest level of 30% would equate to approximately $43 per procedure. The $43 price is equivalent to reducing OOP costs to 20% of our baseline cost of surgery ($200). This highlights the need for comprehensive financial risk

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**Figure 2** Percentage of the population protected from catastrophic expenditure or impoverishment in each wealth quintile if out-of-pocket expenses were reduced to 30%.
protection in rural areas in LMICs, particularly among the poorest communities.

Our data strongly support the need for protecting the poorest communities in LMICs from catastrophic health expenditures and impoverishment, and that reducing OOP costs related to healthcare is not enough. The main reductions in risk of catastrophic expenditures and impoverishment through reduction of OOP costs for surgical care are seen only among the richest wealth quintiles with the bottom two quintiles’ risks only reducing to less than 5%. These findings are consistent with literature in other health areas indicating that OOP payments often lead to higher rates of impoverishment among the most vulnerable populations.44–46 This suggests that in addition to reduction of OOP costs for surgical care, alternative funding streams are required to protect these communities, including universal health coverage frameworks.16

Expanding basic surgical coverage through health insurance is an important adjunct for improving healthcare utilisation and protecting households from catastrophic expenditure and impoverishment from OOP expenses.47 For surgical care for children, the breadth of universal health coverage should include financial risk protection from OOP plus national health care protection, including free healthcare and adequate insurance provisions.

The main limitations of the study are the use of proxy financial measures and lack of data availability. A proxy was used in place of the average cost of a surgical procedure in order to estimate the risk of catastrophic expenditure and impoverishment. In the absence of paediatric surgery-specific cost data, we used proxy measures of costs related to surgical procedures in adults for a range of countries from Gibbons et al31 as well as data from the Lancet Commission on Global Surgery for a caesarean section.30 We used the midpoint unit cost between low-income countries and lower middle-income countries as our baseline estimate of $200 per paediatric surgical procedure.30 A caesarean section is considered one of the three bellwether procedures in global surgical care, and typifies a hospital system’s capacity to perform most other types of surgical procedure.17 The $200 direct medical cost includes costs for preoperative evaluation, hospital care and routine postoperative care as well as the recurrent costs of running a surgical service such as salaries, utilities, equipment, medical supplies and medicines. To assess face validity of the $200 unit cost, we compared the estimated costs of common paediatric surgical procedures from our previous systematic review and our study in Somaliland.32 40 In the systematic review, the unit cost for paediatric surgical procedures ranged from $215 for various general surgery conditions, $608 for various neurological conditions, $130–$368 for various orthopaedic conditions and $384–$480 for various conditions requiring reconstructive surgery. In addition, our previous study in Somaliland found the average cost for a caesarean section was $170 (see online supplemental table 1). Thus, our estimate of $200 per unit cost is a conservative proxy estimate. We acknowledge that this
### Table 3  Sensitivity analyses of risk of catastrophic expenditure and impoverishment

<table>
<thead>
<tr>
<th>Catastrophic expenditure</th>
<th>Baseline ($200)</th>
<th>Low end ($130)</th>
<th>High end ($608)</th>
<th>Baseline ($200)</th>
<th>Low end ($130)</th>
<th>High end ($608)</th>
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<tbody>
<tr>
<td>Overall</td>
<td>% risk (CI)</td>
<td>% risk (CI)</td>
<td>% risk (CI)</td>
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<tr>
<td><strong>Catastrophic expenditure</strong></td>
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<tr>
<td>Baseline ($130)</td>
<td>98.4 (89.7, 100.0)</td>
<td>81.9 (40.5, 99.4)</td>
<td>100.0 (100.0, 100.0)</td>
<td>–</td>
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<tr>
<td>50% of baseline</td>
<td>87.9 (52.6, 99.8)</td>
<td>53.4 (9.6, 94.0)</td>
<td>100.0 (100.0, 100.0)</td>
<td>10.5 (0.2, 37.1)</td>
<td>0.0 (0.0, 0.0)</td>
<td>28.5 (4.5, 30.9)</td>
</tr>
<tr>
<td>30% of baseline</td>
<td>46.1 (6.2, 91.0)</td>
<td>16.5 (2.0, 60.3)</td>
<td>99.9 (98.9, 100.0)</td>
<td>52.3 (9.0, 83.5)</td>
<td>0.1 (0.0, 1.1)</td>
<td>65.4 (39.1, 40.3)</td>
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<tr>
<td>Baseline ($130)</td>
<td>97.8 (85.4, 100.0)</td>
<td>76.0 (28.7, 99.2)</td>
<td>100.0 (100.0, 100.0)</td>
<td>–</td>
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<td>–</td>
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<td>50% of baseline</td>
<td>83.6 (40.0, 99.7)</td>
<td>43.3 (4.0, 90.6)</td>
<td>100.0 (100.0, 100.0)</td>
<td>14.2 (0.3, 45.4)</td>
<td>0.0 (0.0, 0.0)</td>
<td>32.7 (8.6, 24.7)</td>
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<td>30% of baseline</td>
<td>35.7 (2.3, 86.8)</td>
<td>10.1 (0.0, 50.6)</td>
<td>99.8 (98.6, 100.0)</td>
<td>62.1 (13.2, 83.1)</td>
<td>0.2 (0.0, 1.4)</td>
<td>65.4 (39.1, 40.3)</td>
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<td><strong>Rural areas</strong></td>
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<tr>
<td>Baseline ($130)</td>
<td>95.3 (85.4, 99.5)</td>
<td>81.2 (58.1, 95.9)</td>
<td>100.0 (100.0, 100.0)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>50% of baseline</td>
<td>85.4 (64.2, 97.4)</td>
<td>63.8 (33.8, 88.6)</td>
<td>100.0 (100.0, 100.0)</td>
<td>9.9 (2.1, 21.2)</td>
<td>0.0 (0.0, 0.2)</td>
<td>17.4 (7.3, 24.3)</td>
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<tr>
<td>30% of baseline</td>
<td>59.1 (28.7, 86.0)</td>
<td>36.5 (10.6, 68.9)</td>
<td>98.7 (94.9, 99.7)</td>
<td>36.2 (13.5, 56.7)</td>
<td>1.3 (0.1, 5.1)</td>
<td>44.7 (27.0, 47.5)</td>
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<td><strong>Impoverishment $1.90 (extreme poverty)</strong></td>
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</tr>
<tr>
<td>Baseline ($130)</td>
<td>47.2 (29.4, 66.3)</td>
<td>38.5 (23.3, 56.6)</td>
<td>84.7 (70.2, 95.1)</td>
<td>–</td>
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</tr>
<tr>
<td>50% of baseline</td>
<td>40.0 (24.2, 58.3)</td>
<td>33.9 (20.2, 51.3)</td>
<td>72.3 (53.9, 87.7)</td>
<td>7.2 (5.2, 8.0)</td>
<td>4.6 (3.1, 5.3)</td>
<td>12.4 (7.4, 16.3)</td>
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<tr>
<td>30% of baseline</td>
<td>32.9 (19.2, 50.2)</td>
<td>29.2 (16.8, 44.9)</td>
<td>54.4 (35.7, 73.4)</td>
<td>14.3 (10.2, 16.1)</td>
<td>9.3 (6.5, 11.7)</td>
<td>30.3 (21.7, 34.5)</td>
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<tr>
<td><strong>Urban areas</strong></td>
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<tr>
<td>Baseline ($130)</td>
<td>34.5 (18.8, 54.3)</td>
<td>71.6 (53.9, 86.8)</td>
<td>78.7 (60.3, 92.4)</td>
<td>–</td>
<td>–</td>
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<tr>
<td>50% of baseline</td>
<td>27.6 (14.2, 45.3)</td>
<td>67.9 (50.1, 83.5)</td>
<td>62.9 (42.1, 82.1)</td>
<td>6.9 (4.6, 9.0)</td>
<td>3.7 (3.3, 3.8)</td>
<td>15.8 (10.3, 18.2)</td>
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<tr>
<td>30% of baseline</td>
<td>21.0 (10.5, 36.2)</td>
<td>64.4 (46.8, 81.4)</td>
<td>42.2 (24.1, 62.9)</td>
<td>13.5 (8.3, 18.1)</td>
<td>7.2 (5.4, 7.3)</td>
<td>36.5 (29.5, 36.2)</td>
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<td><strong>Rural areas</strong></td>
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<tr>
<td>Baseline ($130)</td>
<td>61.0 (50.7, 71.6)</td>
<td>55.9 (46.0, 66.4)</td>
<td>92.0 (86.3, 96.3)</td>
<td>–</td>
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<tr>
<td>50% of baseline</td>
<td>56.9 (46.7, 67.3)</td>
<td>53.0 (43.1, 63.3)</td>
<td>88.4 (81.4, 94.1)</td>
<td>2.3 (1.8, 2.3)</td>
<td>2.9 (2.8, 3.1)</td>
<td>3.6 (2.2, 4.9)</td>
</tr>
<tr>
<td>30% of baseline</td>
<td>52.7 (42.8, 63.2)</td>
<td>50.2 (40.8, 60.3)</td>
<td>83.4 (75.4, 90.4)</td>
<td>4.7 (4.0, 5.1)</td>
<td>5.7 (5.2, 6.1)</td>
<td>8.6 (5.9, 10.9)</td>
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<td><strong>Impoverishment $3.10 (poverty)</strong></td>
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<tr>
<td>Baseline ($130)</td>
<td>83.9 (70.1, 93.9)</td>
<td>79.4 (64.8, 91.4)</td>
<td>96.9 (91.7, 99.5)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>50% of baseline</td>
<td>80.3 (65.6, 91.6)</td>
<td>76.7 (61.6, 89.6)</td>
<td>93.4 (85.0, 98.3)</td>
<td>3.6 (2.3, 4.5)</td>
<td>2.7 (1.8, 3.2)</td>
<td>3.8 (1.2, 6.7)</td>
</tr>
<tr>
<td>30% of baseline</td>
<td>76.1 (61.0, 88.9)</td>
<td>73.6 (58.2, 87.1)</td>
<td>87.1 (74.7, 95.5)</td>
<td>7.8 (5.0, 9.1)</td>
<td>5.8 (4.3, 6.6)</td>
<td>9.8 (4.0, 17.0)</td>
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Continued
approximation could differ from Somaliland’s exact financial strain on individual families depending on the surgical care received. Second, the information gathered regarding OOP estimates from our hospital assessment was collected from representatives at each hospital. There is a potential for recall bias on these estimates and we aimed to minimise this bias by asking several stakeholders from each hospital across a wide spectrum of expertise, including clinical and administrative. Lastly, our analyses modelled reducing OOP costs only and did not incorporate other comprehensive interventions that could likely make a larger impact. Next step modelling studies should include broader interventions such as reducing OOP costs in addition to providing health insurance, financial vouchers, health system strengthening, and/or a combination of these interventions. This would strengthen policy recommendations as the global health community moves toward system-wide, comprehensive interventions rather than siloed approaches.

All United Nations Member States have recognised the financial burden associated with healthcare and have implemented universal health coverage as part of the Sustainable Development Goals for 2030. Although OOP expenditures for healthcare are often cited as the main driver of impoverishment, we found wide disparities in the impact of reduction of OOP payments, with the poorest of the poor remaining at high risk of impoverishment for surgical care. Our findings strongly suggest that comprehensive financial protection is required to prevent risk of catastrophic expenditures and impoverishment in these communities. We suggest several policy recommendations to protect families with children with surgical needs from the risk of financial catastrophe. First, financial risk protection mechanisms beyond reducing OOP costs for the poorest communities are needed. Second, we recommend incorporating surgery-specific provisions into universal healthcare plans and priorities for children, particularly focusing on rural communities. Lastly, we recommend including paediatric surgical provisions into financial protection and universal healthcare movements.

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Contributors ERS, PK, TR and MCS conducted the data analysis, and assisted in data interpretation and manuscript writing. MM, SD, TC, CC-C and EAI assisted in data interpretation and manuscript writing. ERS and HER conceptualised the study.

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<th>Baseline ($200)</th>
<th>Low end ($130)</th>
<th>High end ($608)</th>
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<tr>
<td>50% of baseline</td>
<td>72.8 (65.4, 80.7)</td>
<td>78.6 (73.1, 83.4)</td>
<td>74.6 (64.7, 84.2)</td>
</tr>
<tr>
<td>30% of baseline</td>
<td>67.5 (63.0, 72.0)</td>
<td>75.3 (66.5, 83.8)</td>
<td>65.0 (54.5, 75.4)</td>
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</table>

Overall % risk (CI)

<table>
<thead>
<tr>
<th>Baseline</th>
<th>Low end</th>
<th>High end</th>
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<tr>
<td>50% of baseline</td>
<td>72.8 (65.4, 80.7)</td>
<td>78.6 (73.1, 83.4)</td>
</tr>
<tr>
<td>30% of baseline</td>
<td>67.5 (63.0, 72.0)</td>
<td>75.3 (66.5, 83.8)</td>
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</table>

Table 3
oversaw all analyses, and assisted in data interpretation and manuscript writing. ERS is responsible for the overall content as the guarantor of this study.

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**Competing interests** None declared.

**Patient and public involvement** Patients and/or the public were not involved in the design, conduct, or reporting, or dissemination plans of this research.

**Patient consent for publication** Not required.

**Ethics approval** This study involves human participants and Institutional Review Board (IRB) approval was granted by Duke University. Since Somaliland does not have a national IRB, a formal letter of approval for the study was granted by the Somaliland Ministry of Health (Duke IRB-Protocol: 2017-0205; E0171). Participants gave informed consent to participate in the study before taking part.

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

**Data availability statement** Data are available upon reasonable request.

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