World J Surg
https://doi.org/10.1007/s00268-023-06952-3

SURGERY IN LOW AND MIDDLE INCOME COUNTRIES

Exploring the Use of a Fit-for-Purpose Surgical Headlight in Sub-Saharan Africa: Mixed Methods Study

Muaad Hussien[1] · Nina Capo-Chichi[2,3] · Nichole Starr[3,4] · Samuel Negash[3,5] · Terseer Utam[3,7] · Tihitena Negussie[3,6] · Katie Fernandez[3] · Thomas G. Weiser[3,8,9]

Accepted: 27 January 2023

Abstract

Background High-quality surgical lighting is often lacking in low-resource settings. Commercial surgical headlights are unavailable due to high cost and supply and maintenance challenges. We aimed to understand user needs of a surgical headlight for low-resource settings by evaluating a preselected robust but relatively inexpensive headlight and lighting conditions.

Methods We observed headlight use by ten surgeons in Ethiopia and six in Liberia. All surgeons completed surveys about their lighting environment and experience using headlight, and were subsequently interviewed. Twelve surgeons completed logbooks on headlight use. We distributed headlights to 48 additional surgeons, and all surgeons were surveyed for feedback.

Results In Ethiopia, five surgeons ranked operating room light quality as poor or very poor; seven delayed or cancelled operations within the last year and five described intraoperative complications due to poor lighting. In Liberia, lighting was rated as "good", however fieldnotes, and interviews noted generator fuel-rationing, and poor lighting conditions. In both countries, the headlight was considered extremely useful. Surgeons recommended nine improvements, including comfort, durability, affordability and availability of multiple rechargeable batteries. Thematic analysis identified factors influencing headlight use, specifications and feedback, and infrastructure challenges.

Conclusion Lighting in surveyed operating rooms was poor. Although conditions and need for the headlights differed between Ethiopia and Liberia, headlights were considered highly useful. However, discomfort was a major limiting factor for ongoing use, and the hardest to objectively characterise for specification and engineering purposes. Specific needs for surgical headlights include comfort and durability. Refinement of a fit-for-purpose surgical headlight is ongoing.

✉ Muaad Hussien
muaad.hussien@gmail.com

[1] Department of Surgery and Urology, Mälarsjukhuset Hospital, Eskilstuna, Sweden

[2] Smile Train, New York, USA

[3] Lifebox Foundation Inc., New York, USA

[4] Department of Surgery, University of California San Francisco, San Francisco, CA, USA

[5] Department of Surgery, Menelik II Hospital, Addis Ababa, Ethiopia

[6] Department of Surgery, Addis Ababa University, Addis Ababa, Ethiopia

[7] Department of Surgery, Redemption Hospital, New Kru Town, Monrovia, Liberia

[8] Department of Surgery, Stanford University, Stanford, CA, USA

[9] Department of Clinical Surgery, Royal Infirmary of Edinburgh, University of Edinburgh, Edinburgh, UK

Published online: 02 March 2023

Background

Lack of safe surgical care is a global health problem. Postoperative mortality rates are disproportionately higher in low- and middle-income countries (LMICs), and safe surgery requires essential resources and equipment, including reliable, high-quality lighting [1, 2]. In LMICs, an estimated 24 million patients per year are at risk from inadequate or unreliable lighting during surgery [3]. Intermittent lighting due to power outages, substandard or broken surgical lighting and complete lack of surgical-quality lighting are all aspects of the problem. In a survey of 100 surgeons in 39 LMICs, 48% indicated their facility experienced frequent power outages [4]. Even in facilities with a backup-generator, there is a lighting delay when switching from mains to generator power which can lead to gaps in safe surgical lighting during an operation. It is estimated that 40% of medical devices in LMICs are out of service or broken as almost all devices are designed for high income settings as well as lack spare parts, installation expertise, accessories and space [5, 6].

Surgical headlights are not accessible or affordable for many surgeons in LMICs. Many surgical headlights are designed to be connected to mains power, which is neither convenient nor continuously available in resource-constrained settings. Over the past several years, Lifebox, a charity organisation focused on improving surgical safety globally, has field tested surgical headlight models and identified minimum specifications for a surgical headlight for resource-constrained settings [3, 7]. Based on iterative feedback and a human-centred design approach, we identified a high-performing industrial-grade headlight that appeared acceptable and affordable for widespread distribution and use. To inform further iterative work with the manufacturer to modify the light for surgical use, we undertook a mixed methods assessment of environment, working conditions, and field use of this device.

Methods

The study design was a mixed methods strategy consisting of surveys, field observations and fieldnotes, photographs, videos, surveys, questionnaires, logbooks, and interviews. Data collection was conducted in Ethiopia over five weeks, between September and October 2019 and in Liberia over 2 weeks in November 2019. Follow-up data were collected in 2020 and 2021.

We used purposeful sampling to engage ten surgeons in Ethiopia and six surgeons in Liberia working across a number of hospitals and specialties (Fig. 1) who we knew to be reliable and interested in quality improvement. We distributed headlights for each of these surgeons, who then completed surveys, logbooks, interviews and a follow-up (Fig. 2). A second round of distributions was conducted in Liberia (n = 45) and Ethiopia (n = 3) in February 2020 due to lighting needs expressed by local surgeons and for follow-up purposes.

Data collection tools

Surgeons completed a baseline survey (Appendices 1 and 2) focusing on existing lighting conditions and their impact on patient care in hospitals, perceptions of headlights and their use. They were then provided a high-quality, durable, industrial-grade headlight with one rechargeable and one alkaline battery pack. This headlight was not one designed specifically for medical or surgical use, but had previously been shown to be highly effective for illuminating the surgical field [5]. The survey used in data collection in Liberia was slightly adapted due to short duration of surveying in Liberia and time constraints while interviewing.

We recorded videos of surgeons' initial encounters with the headlight upon first receiving the device.

We developed logbooks (Appendix 3) during summer of 2019, based on logbooks from a previous headlight study [7]. The surgeons were asked to complete the logbook after each operation they performed while wearing the headlight. The logbooks were collected during structured interviews following a pre-established period of headlight use: two weeks for Ethiopia, one week for Liberia.

In Ethiopia, interviews with ten surgeons were conducted following two weeks of use and experience with the headlight. In Liberia, interviews were conducted after one week of headlight use. Consent was taken and recorded interviews were transcribed for qualitative analysis. The interview guide (Appendix 4) was based on prior guides developed through an iterative process.

We transcribed Ethiopia interviews and coded their content which were iteratively grouped and then gathered into four themes forming a codebook. After transcription and analysis of Liberia interviews, the codebook was streamlined and updated with new Liberia related codes (Table 1). Fieldnotes, photographs, postoperative questions and videos were used as corroborating and validating material in qualitative analysis of interviews. Statistical and qualitative analysis was performed using MS Excel.

Two follow-up surveys for Ethiopia and Liberia were conducted online (Appendix 5), in December 2020 and June 2021. All surgeons who had received lights were approached for follow-up to maximise the response rate. Surgeons who were initially recruited for this study as well as surgeons from Liberia and Ethiopia who received additional headlights were requested to fill out an

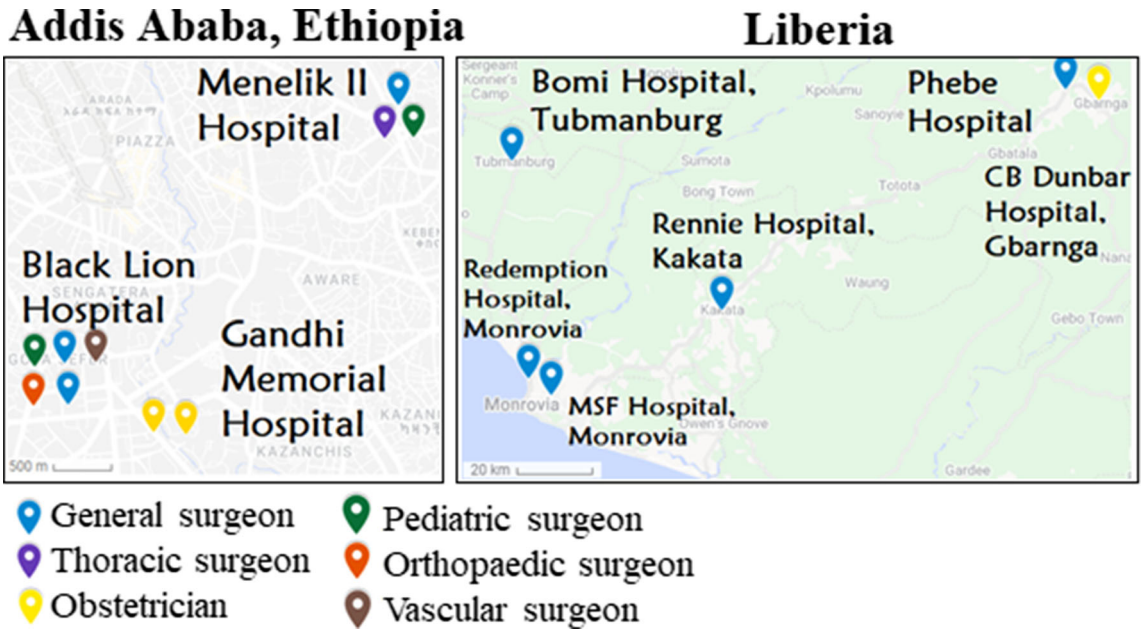


Fig. 1 Surgeons who received the headlights and were observed and interviewed for the study (n = 16)

anonymous online survey on frequency of use of and problem with headlight, possible solutions, whether they would recommend it and if they would purchase this device with their own funds at price of $175 (estimated cost of manufacturing and distribution).

Results

Baseline survey

All 10 Ethiopian and six Liberian surgeons involved in testing completed the baseline survey. In Ethiopia, half of the surgeons considered the quality of lighting in their operating theatre to be poor or very poor. Electricity failures while operating were common; four surgeons experienced them most days, two experienced them weekly and one surgeon experienced them three to four times per day. Ethiopian facilities had backup-generators available in varying degrees; only 3 surgeons described them as always available, while six said they were sometimes available and one that they were very unreliable.

During a power failure, surgeons used different methods for backup lighting; in Ethiopia, mobile phone light use was as frequent as relying on backup-generators (7/10) whereas in Liberia mobile phones (3/6) and flashlights (3/6) were identified as backup lighting. In Ethiopia, six surgeons delayed or cancelled operations due to poor lighting, with five of them reporting this at least once per month. In Liberia, two surgeons reported delays or cancellations. Eight Ethiopian and four Liberian surgeons reported lack of in-country availability for purchase of headlights was the main barrier to access.

Current lighting was considered a significant risk to patient safety by eight Ethiopian surgeons, and six knew of a patient who came to harm because of poor lighting. In Liberia, one surgeon considered lighting a significant risk and two surgeons considered it a small risk.

Logbooks

Logbooks recording 41 operations were acquired from nine Ethiopian surgeons from six different surgical specialties (Table 2). In majority of the cases, surgeons reported the headlight as bright enough, spot diameter appropriate, easily adjustable and comfortable. However, in 9 (22%) cases, the headlight became so dim during operation, the surgeon could not use it; in 5 (12%), the battery ran out of charge.

Logbooks recording 8 operations were acquired from three Liberian surgeons from two specialties. The rest of the surgeons did not fill it or were not available. In all cases, the headlight was deemed bright enough, spot diameter appropriate, easily adjustable, comfortable, light stayed in place and the light angle considered appropriate.

Interview results

All 16 surgeons completed interviews. We identified four major themes from interview data: factors influencing

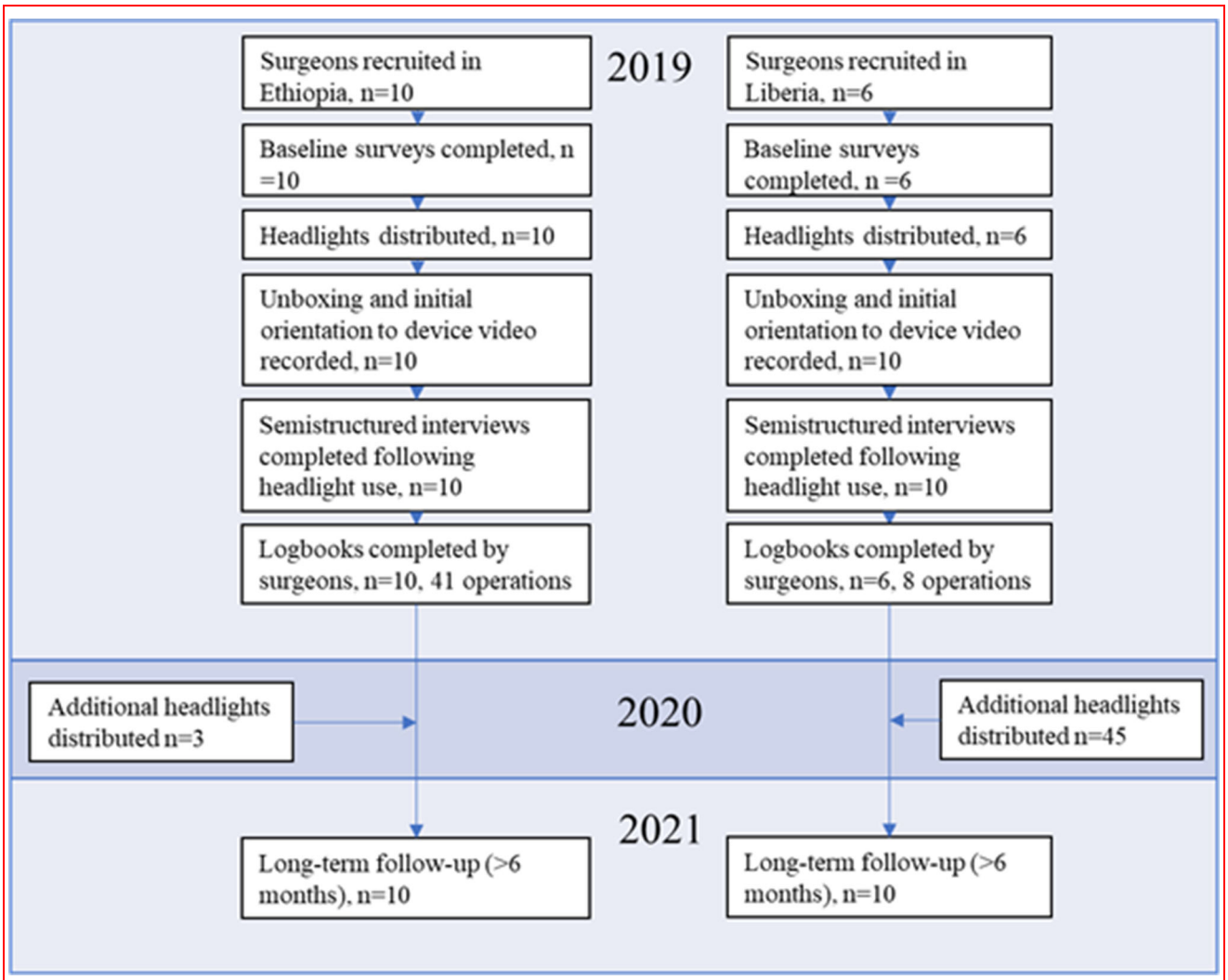


Fig. 2 Study flow chart

headlight use and utility, device and specification feedback, device improvement and considerations, and existing hospital infrastructure (Table 1). These factors were of high importance to surgeons in both settings, although specific considerations varied between sites and countries.

Factors influencing headlight use and utility

The headlight was perceived as useful in visualising vascular and gynaecologic structures, and for treating trauma. All surgeons in Ethiopia and three in Liberia indicated that the headlight was useful in visualising deep structures while operating in body cavities: *"it's very useful like in chest and deep in pelvis, in retroperitoneum it is very important"*. A perceived barrier to long-term use of headlights was lack of a good supply chain for replacement parts and access to maintenance services. Some Ethiopian surgeons reported that in the past, they had to discard equipment, including past headlights, after malfunction due to lack of access to maintenance or service support; malfunction of the headlight bulb and loosening of the hinge of the headlight were mentioned as examples of potential concern in Ethiopia.

Device and specification feedback

Though adjustability of headlight was found to be appropriate by all surgeons in Ethiopia and three in Liberia, its wearability was an issue. Discomfort was reported by five surgeons, who felt it on their forehead through the headlight apparatus itself, the heat it produced, or the tight headband. The brightest setting with the narrowest spotlight was preferred by all Ethiopian surgeons.

Table 1 Thematic results of qualitative interviews

Thematic issue (grandparent code)	Primary code	Subcode	Frequency of reporting during interviews	
			Ethiopia	Liberia
Factors influencing headlight use and utility	Benefits of use in OR	Added confidence with additional light source	8	5
		Improved team dynamics	4	1
		Improved visualisation of anatomy	20	4
		Light valued in multiple practice settings	2	1
	Challenges to use in OR	Additional light not perceived to be helpful	5	2
		Interference with other team members	2	0
	Headlight distribution	Additional headlight for surgical team	5	3
		Affordability	4	0
		Universal need for lights	13	3
	Headlight maintenance	Access to maintenance services	4	0
		Supply chain for replacement parts	7	0
Device and specification feedback	Battery attributes	Backup batteries sufficient	9	2
		Battery life short	9	1
		Battery placement	0	1
		Battery life sufficient	15	1
	Recharge in office		5	0
	Fit & comfort	Adjustability appropriate	14	4
		Appears durable	3	0
		Comfort on head	5	0
		Lightweight to wear	5	1
		Tilt angle is acceptable	3	0
		Uncomfortable to wear	13	2
	Light settings	Light specifications satisfactory	6	1
		Prefer brightest setting	10	0
		Prefer wide diameter	0	1
		Prefer narrowest diameter	7	0
	Storage and ownership	Shared ownership	0	8
		Personal ownership	16	0
Device improvement and considerations	Battery function	Charge level indicator	2	0
		Increase battery life	3	0
	Improve comfort		10	0
	Light intensity	Increase brightness	14	0
	Light quality	Improve spotlight uniformity	5	0
		Warmer light hue	4	0
	Packaging and assembly	Additional attachments	3	4
		Provide additional rechargeable batteries	6	0
		Reduce battery size	2	0
		Streamline packaging	4	0

Table 1 continued

Thematic issue (grandparent code)	Primary code	Subcode	Frequency of reporting during interviews	
			Ethiopia	Liberia
Existing hospital infrastructure	Backup lighting during power failure	Handheld flashlights used	2	0
		Other surgical headlights	0	1
		Solar energy light	0	1
		Mobile Phone lights	9	0
		No backup source	1	0
	Electricity failures	High frequency of power cuts	7	1
		Fuel rationing or shortage	0	3
		Unreliable generators	7	0
	Global shortage of resources	Lack of beds & medication	1	0
		Lack of instruments	4	0
		Lack of water	1	0
	Lighting impact on patient outcomes	Bleeding	6	0
		Deep cavity visualisation	10	3
		Delays, transfers and cancellations	3	1
	Suboptimal overhead OR lighting	Dim overhead lighting	6	3
		Lack of standard operating room lights	4	0
		Overhead light malfunction	4	0
		Overhead light not adjustable	4	3

Table 2 Results of logbook recordings of headlight features following surgery

Headlight feature	Ethiopia (n = 41 operations)	Liberia (n = 8 operations)
Bright enough	39 (95%)	8 (100%)
Spot diameter: adequate	33 (80%)	8 (100%)
headlight angle easily adjustable	40 (98%)	8 (100%)
Headlight angle adjusted during surgery	19 (46%)	5 (63%)
Comfortable	30 (73%)	8 (100%)
Battery: ran out of charge	5 (12%)	0
Battery: light became too dim	9 (22%)	0

Device improvements and considerations

Brightness and light duration were considered the most important issues to increase and improve. Four surgeons requested an increased battery life; two surgeons requested a charge level indicator to see remaining battery life; seven surgeons wanted brighter lights.

Existing hospital infrastructure

Fieldnotes, photographs, and direct observations confirmed that the existing lighting and electricity infrastructure in the eight surveyed hospitals was poor. Overhead surgical lights were too dim, difficult to adjust for proper surgical field visualisation and sometimes simply not functional. In rural areas, operations were often performed under regular ceiling bulb light or natural light.

Power cuts were frequent and could last up to 15 min, resulting in surgeons using mobile phone lights and battery-powered torches during an outage. In Ethiopia, backup-generators were not properly maintained and were unreliable; in Liberia, hospitals relied solely on generators for electricity, leaving them vulnerable to malfunctions and fuel shortages. Fuel shortages in rural areas led to referrals of patients elsewhere.

Most surgeons (14 out of 16) reported that current light in their operating theatres negatively impacted patient outcomes; for example, bleeding was difficult to control in dim light or when lights shut down. Deep cavity visualisation was difficult with current surgical overhead or ceiling lights. Poor lighting led to delays, transfers, and cancellations. In addition, three Ethiopian surgeons reported that bad lighting impacted how well an anastomosis was performed.

Longer term follow-up results

Longer term follow-up data were received from 20 surgeons over a year after initial distribution (Table 3); seven respondents were part of the original group, while 10 received headlights through the secondary distribution.

These surgeons reported an average of eight operations per week with the headlight used for 30% of them; three surgeons had stopped using the headlight. The main reasons for not using the headlight were it not being deemed necessary for procedure and discomfort. Surgeons reported the best feature of the headlight was brightness/field of vision, long battery life, compact battery and rechargeable battery.

Most of the surgeons (16 out of 20) reported the headlight contributed to their capacity to provide safe surgery, while 12 reported it increased their confidence, 9 said it reduced delays/cancellations and 8 reported it improved outcomes. 16 of the surgeons reported they would recommend the headlight to their colleagues and 2 would only recommend it to surgeons in rural areas because of its discomfort and that it is not necessary in centres with good lighting.

Table 3 Longer term follow-up results

	Ethiopia, $n = 10$	Liberia, $n = 10$	Total
Average number of operations per week (mean ± SD)	7.6 (± 2.5)	9.4 (± 4.9)	8.5 (± 3.9)
Average % headlight use per week (mean ± SD)	21.5% (± 18.4)	42.0% (± 33.6)	31.8% (± 28.4)
Reasons for not using the headlight			
Not comfortable	4	0	4
Not necessary	5	4	9
Best feature of the headlight			
brightness/field of vision	7	1	8
Long battery life	4	0	4
Compact battery	1	2	3
Rechargeable battery	1	1	2
Features that could use the most improvement			
Comfort	8	1	9
Battery issues	0	5	5
Headlight contribution			
Capacity to provide safe surgery	6	10	16
Increased confidence	5	7	12
Reduce delays/cancellations	3	6	9
Improve outcomes	2	6	8
Reason for not recommending the headlight to colleagues			
Not comfortable	2	0	2
Not necessary	2	0	2
Reasons for recommending the headlight to colleagues			
Useful in cases of power interruption	2	6	8
Good brightness	2	2	4
Affordable	1	0	1
Would purchase the headlight for $175	3	8	12

Discussion

Our study confirmed that operating room light quality was poor and light disruptions during surgery were common in both Ethiopia and Liberia. In Liberia, we also found every surveyed hospital relying primarily on a generator for electricity. In both countries, unreliability of generators, stemming either from fuel shortages or supply chain shortcomings, leads to delays and cancellations of operations.

The core problem was ultimately unreliability of lighting, and its inability to sufficiently illuminate the surgical field. Surgeons felt that reliable access to appropriate lighting would decrease unnecessary complications, the need to delay operations, or transfer patients to other institutions. Use of a well-functioning headlight improved surgeon confidence in surgical field visualisation, and safely completing the technical steps, especially in deep body cavities. Furthermore, while it was not specifically part of our study, we noted cases with many people, sometimes up to seven scrubbed staff members, bent over the surgical field obstructing the overhead theatre light; there was also a lack of plastic sterile handles to adjust the overhead light, making surgical field illumination adjustment difficult.

Although many headlight features were appreciated, comfort was a major barrier to ongoing use and requires improvement; this is the least quantifiable specification and difficult to standardise. The positioning of the battery behind the head on the band itself contributed to this, but the option to put on the waist was not always recognised and could be encouraged by including a descriptive instruction guide with the headlight. Although the

headlight is a simple medical device, issues such as bulb breaking, headband wearing out, lamp hinge loosening, or malfunction of the rechargeable battery are concerns needed to be taken into consideration during design.

Having a fit-for-purpose headlight would facilitate illumination and even offload the work of assistants who currently have to scramble to find and illuminate mobile phone lights or battery-powered torches when the power shuts off. Besides being inadequate as an illumination device, mobile phone lighting is unstable, not controlled by the surgeon, an infection risk, and frequently obstructs both the movement and visualisation of the surgeon.

Limitations of our study include the small number of surgeons involved. Resources were variable, particularly between Ethiopia and Liberia, but also within countries. Different resource levels across institutions likely affected the responses surgeons provided. Headlight availability was still highly valued across all resources levels, indicating an unmet need for the lighting challenges. Long-term follow-up responses of surgeons who received a device were low, mainly due to busy clinical schedules, the pandemic, logistical issues and poor internet. Anecdotally, there seems to be ongoing high use of the distributed headlights, especially in Liberia, but work is ongoing to determine device failure rates as well as use preferences of surgeons over time. The time for researchers to work in Liberia was shorter and the surgeons more difficult to reach intraoperatively with busier schedules, which is why baseline surveys were shortened. Anecdotal and discussion generating questions such as desired headlight qualities as well as patients harmed by poor lighting were removed and background information was also simplified, leading to less comparable results between the two countries. Time constraints led likely to the low logbook capture rate in Liberia.

In conclusion, lighting is a surgical safety problem in Ethiopia and Liberia due to its unreliability and inadequacy to illuminate the surgical field. In both countries, the surgical headlight distributed by Lifebox was well received by surgeons; they felt that having a headlight decreased the need to delay surgery or transfer cases, although our data were anecdotal and the study was not designed or powered to detect such events. Due to time constraints, there is less survey data from Liberia, but the interviews followed the same structure providing rather comparable results. Comfort was a major barrier and requires more work in a subsequent version of the headlight. Based on this feedback, a modified headlight is under review with plans for further field testing in multiple low-income environments.

Appendix 1 Baseline surveys in Ethiopia

Baseline survey

lifebox
Saving lives through safer surgery

* 1. Which of these best describes your hospital?

If you work in many hospitals, please complete for the hospital where you work the most. If you

are a visiting surgeon, please complete for the main hospital you visit.

- Rural health clinic / health centre
- District hospital
- First referral hospital
- Regional / national referral hospital
- Private clinic / health centre
- Private hospital
- Other (please specify)

Please answer all the following questions based on this hospital

* 2. Overall, how would you rate the quality of the lighting in your operating theatre?

By quality, we mean the ability to consistently illuminate the surgical field

- Very poor
- Poor
- Good
- Excellent

* 3. How often do you experience main electricity power failures while operating?

- Many times each day
- Most days
- Weekly
- Monthly
- Less often than monthly
- Never
- Other (please specify)

* 4. Does your facility have a backup generator?

- Yes - always available
- Yes - sometimes available
- Yes - very unreliable
- No
- Do not know
- Other (please specify)

* 5. What do you do in your operating theatre when there is a main power failure?

(check all that apply)

- Use mobile phone light
- Use a torch / other battery operated light
- Use a headlight
- Stop operating
- Rely on the backup generator
- Not applicable (No powercuts)
- Other (please specify)

* 6. Do you ever delay or cancel operations due to poor lighting?

- No
- Yes
  - If yes, how often do you have to do this?

* 7. Do you use a surgical headlight for operating?

- Yes, always
- Yes, occasionally
- No
  - If No, please explain why

* 8. What 5 features would be most important to you for a surgical headlight?

Please select 5 options from the 10 available

- Rechargeable battery
- Ability to adjust diameter of light focus
- Ability to change brightness of the light
- Compatibility with eyeglasses and surgical loupes

- Separate belt/pocket battery pack
- Lightweight on head
- Easy to carry around
- Durable
- Pure white light
- Comfortable fit
- Other (please specify)

* 9. How much would you spend on a high quality headlight with the above features, in USD ($)?

* 10. What do you see as the main barrier(s) for having a surgical headlight?

- (check all that apply)
- The cost of specific surgical headlights make it unaffordable for me
- Never thought of this as a solution for poor lighting
- Poor suppliers in my country
- Only poor quality/unsuitable headlights available to me
- Uncomfortable to use in my environment
- I do not want one
- Not applicable (there are no barriers / I already have one)
- Other (please specify)

* 11. In general, does the quality of surgical lighting impact the safety for your patients?

By quality, we mean the ability to consistently illuminate the surgical field

- The quality of lighting in my theatre(s) is a significant risk to the safety of my patients
- The quality of lighting in my theatre(s) is a small risk to the safety of my patients
- The quality of lighting in my theatre(s) is not a risk to the safety of my patients

* 12. Do you know of a patient who has come to harm because of poor lighting? (eg. during a power failure)

This can be a patient of yours or a case you heard about

- No
- Yes
- Do not know
- If possible, can you describe what happened

* 13. What country do you work in?

Please complete for the hospital you referred to in question 1

* 14. Are you permanently based here or a visiting surgeon?

- Permanent (or long term resident in this country)
- Visiting surgeon
- Other (please specify)

* 15. What surgical specialty do you practice?

Please choose one that BEST describes your practice

* 16. What is your email address or whatsapp number? (optional)

* 17. Would you like to be included on the Lifebox mailing list to receive updates on this and other projects?

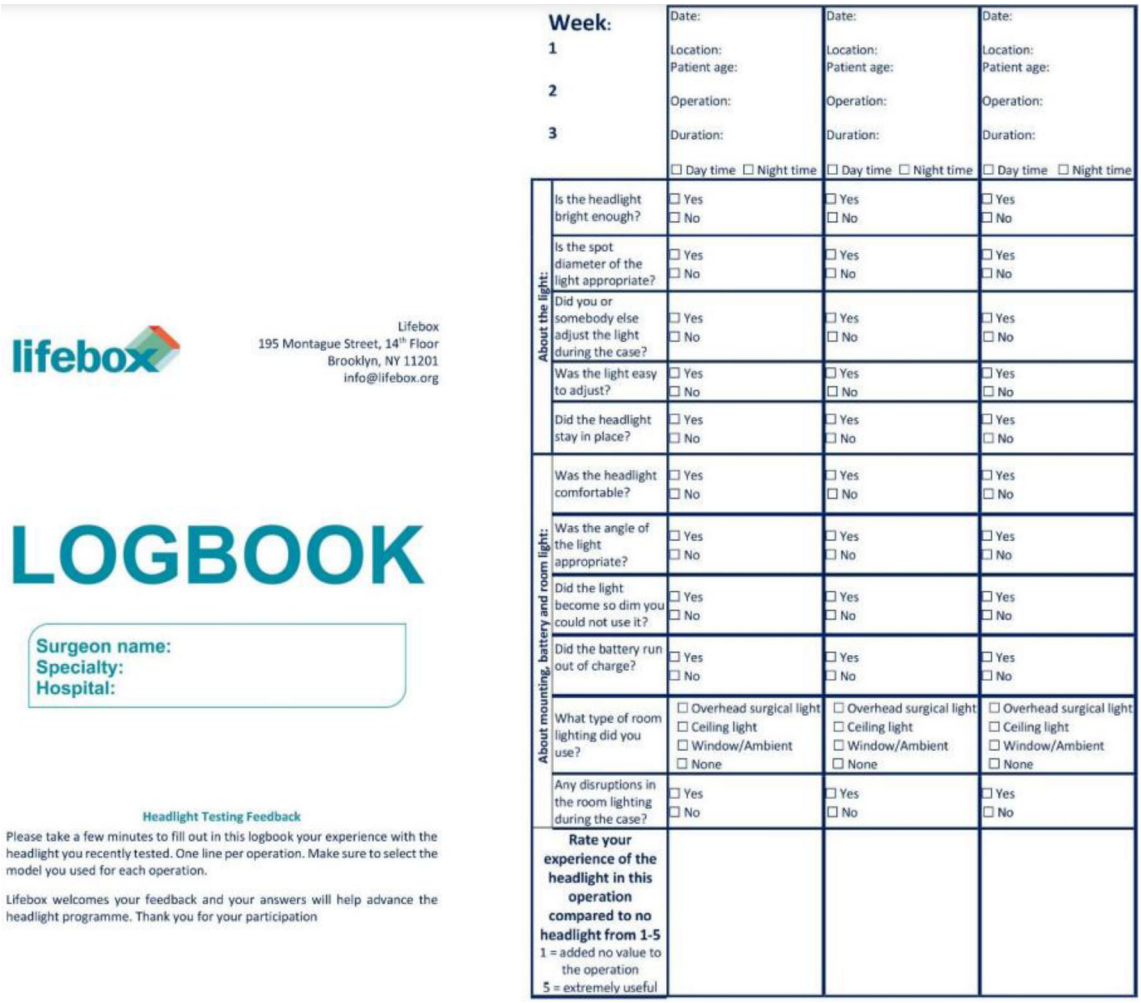
- Yes
- No

* 18. Any other comments you would like to add?

Appendix 2 Baseline surveys in Liberia

Surgical Specialty	
How often does the main power fail?	
	Most days
	Weekly
	Less than monthly
	Never
Generator present and functional?	
	Always available
	Sometimes available
What do you do when power fails in OR?	
	Use mobile phone light
	Use flashlight
	Use headlight
	Stop operating
	Solar system backup
Cases cancelled or delayed due to lighting	Yes/No
Why don't you currently have headlight?	
	Cost
	Never thought to obtain headlight
	Poor supply in my country
	Uncomfortable to use in my environment
	I do not want one
Lighting impact on patient safety	
	Significant risk
	Small risk
	Not a risk

Appendix 3 Logbooks



lifebox

Lifebox
195 Montague Street, 14th Floor
Brooklyn, NY 11201
info@lifebox.org

LOGBOOK

Surgeon name:
Specialty:
Hospital:

Headlight Testing Feedback

Please take a few minutes to fill out in this logbook your experience with the headlight you recently tested. One line per operation. Make sure to select the model you used for each operation.

Lifebox welcomes your feedback and your answers will help advance the headlight programme. Thank you for your participation

	Week: 1 / 2 / 3	Date: Location: Patient age: Operation: Duration: ☐ Day time ☐ Night time	Date: Location: Patient age: Operation: Duration: ☐ Day time ☐ Night time	Date: Location: Patient age: Operation: Duration: ☐ Day time ☐ Night time
About the light:	Is the headlight bright enough?	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
	Is the spot diameter of the light appropriate?	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
	Did you or somebody else adjust the light during the case?	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
	Was the light easy to adjust?	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
	Did the headlight stay in place?	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
About mounting, battery and room light:	Was the headlight comfortable?	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
	Was the angle of the light appropriate?	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
	Did the light become so dim you could not use it?	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
	Did the battery run out of charge?	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
	What type of room lighting did you use?	☐ Overhead surgical light ☐ Ceiling light ☐ Window/Ambient ☐ None	☐ Overhead surgical light ☐ Ceiling light ☐ Window/Ambient ☐ None	☐ Overhead surgical light ☐ Ceiling light ☐ Window/Ambient ☐ None
	Any disruptions in the room lighting during the case?	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
	Rate your experience of the headlight in this operation compared to no headlight from 1-5 1 = added no value to the operation 5 = extremely useful			

Appendix 4 Interview guide

Materials: voice recorder (mobilephone), notebook,

1. Please tell me about yourself. What is your background, present role and how did you end up working here?
2. Please tell me about the lighting in the hospital and the operation theater. Can you please tell me a story of the last time the lighting was insufficient for an operation?
    a. Approximately when and where did the operation take place? What type of operation?
    b. What type of lightings was used?
    c. What was insufficient about the lighting? Is this typical?
3. Please tell me a story of a time lighting affected the outcome of an operation.
    a. Approximately when and where did the operation take place? What type of lighting did you use? What type of operation?
    b. What was insufficient about the lighting?
    c. How many times a year do you believe lighting has affected patient outcomes in your operations?
4. Can you please tell me or show me your working field (offices, wards, operation theaters)?
5. Please show me where you store your headlight.
    a. Do you work at any other sites?
    b. Have you used the headlight at other sites? Why or why not?
    c. Can you please show me the way you carry the headlight to the other sites?
    d. Is the headlight durable enough to withstand transport to and use in different operating theaters?
6. Please tell me about the last time you successfully used the headlight.
7. Please tell me about the last time you had a problem with the headlight.
8. What other challenges have you faced, or do you think might face in the future?
9. Please tell me about the quality of the headlight. How did you feel about the light quality?
10. Please tell me about the battery and lifetime of the light. Was there ever a time when the battery lost power? Is it enough to have 2 batteries?
11. Please tell me about adjusting the light after scrubbing. Who does it?
12. What do your assistants think of the light? Can you please tell me about the last time an assistant or nurse mentioned the headlight or the light in operating theater?
13. Do you prefer using the headlight in certain types of operations? Are there ones where you would never use a headlight?
14. How would you change the headlight to make it better suited for your daily operations?
15. Please tell me about using headlights in the future. How do you feel about them? Where would they be most useful?
16. Anything else to say?

Appendix 5 Longer term follow-up surveys

Lifebox Light: follow-up survey

1. Which hospital are you working in?

2. Which country are you working in?

3. When did you receive the headlight?

4. What is the average number of operations you conduct per week?

5. On average, what PERCENT of operations do you use the headlight for?

6. What is the average number of operations you conduct per week on children (under 18)?

7. What PERCENT of operations on children (under 18) do you use the headlight for?

8. When you choose NOT to use the headlight for a procedure, what are your main reasons? (Select all that apply):

- ☐ Spot diameter too large
- ☐ Spot diameter too small
- ☐ Non-uniform lighting
- ☐ Not comfortable
- ☐ Battery not charged
- ☐ Battery did not last long enough
- ☐ Light not useful for the procedure

9. Has the light had any impact on your ability to provide safe surgery? Please check all that apply

- ☐ No impact
- ☐ Reduced delays
- ☐ Reduced cancellations
- ☐ Increased my confidence
- ☐ Improved outcomes

10. What is the best feature of the Lifebox-provided headlight?

11. What is the feature of the Lifebox-provided headlight that could use the most improvement and why?

12. At a purchase price of $175 including two rechargeable batteries, would you purchase one of these headlight systems with your personal money?

13. Would you recommend this light to your colleague?

14. Please explain why you would or would not recommend it.

15. If you are willing, please provide your name and email address (optional)

Funding Muaad Hussien was supported in part by Karolinska Institutet degree project funding. Nina Capo-Chichi Lifebox Associate Fellow, Nichole Starr Surgical Safety Fellow at Lifebox Foundation, NIH Fogarty International Center (Global Health Equity Scholars NIH FIC D43TW010540),NIH T32 training grant DK007573, Samuel Negash Surgical Safety fellow at Lifebox Foundation, Terseer Utam Surgical Safety fellow at Lifebox Foundation, Tihitena Negussie Global Clinical Director at Lifebox Foundation, Katie Fernandez Chief Programs Officer at Lifebox Foundation, Thomas G Weiser Consulting Medical Officer at Lifebox Foundation, This study was supported in part by Department of Surgery at Stanford University Innovation Seed Grant and UBS Optimus Foundation Grant.

References

1. Biccard BM, Madiba TE, Kluyts HL et al (2018) Perioperative patient outcomes in the African surgical outcomes study: a 7-day prospective observational cohort study. Lancet 391:1589–1598
2. Nepogodiev D, Martin J, Biccard B et al (2019) Global burden of postoperative death. Lancet 393:401
3. Forrester JA, Torgeson K, Weiser TG et al (2019) Minimum specifications for a lifebox surgical headlight for resource-constrained settings. JAMA Surg 154:80–82
4. Forrester JA, Boyd NJ, Fitzgerald JEF et al (2017) Impact of surgical lighting on intraoperative safety in low-resource settings: a cross-sectional survey of surgical providers. World J Surg 41:3055–3065
5. Perry L, Malkin R (2011) Effectiveness of medical equipment donations to improve health systems: how much medical equipment is broken in the developing world? Med Biol Eng Comput 49:719–722
6. World Health Organization (2010) Medical devices: managing the mismatch: an outcome of the Priority Medical Devices project In: Managing the Mismatch, WHO. Geneva, p 3, 56, 94
7. Starr N, Panda N, Johansen EW et al (2020) The lifebox surgical headlight project: engineering, testing, and field assessment in a resource-constrained setting. Br J Surg 107:1751–1761