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Missed opportunity for Nasal Continuous Positive Airway Pressure in preterm neonates with Respiratory Distress Syndrome admitted at tertiary level hospital, New Born Unit in Kenya- A mixed method study.

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Missed opportunity for Nasal Continuous Positive Airway Pressure in preterm neonates with Respiratory Distress Syndrome admitted at tertiary level hospital, New Born Unit in Kenya- A mixed method study.

ABSTRACT

Objectives: To determine the proportion of preterm infants with RDS admitted to the newborn unit at KNH with a missed opportunity for CPAP, and to determine the barriers and facilitators of CPAP utilization.

Design and setting: This was a hospital-based cross-sectional study that employed interactive explanatory concurrent mixed methods.

Participants: Preterm neonates (<37 weeks) within 48 hours of life who met the criteria for CPAP. The key informants were mainly; different staff cadres from the newborn unit, procurement officer, and a biomedical engineer.

Primary and secondary outcome measure: The proportion of preterm infants with RDS admitted to the newborn unit with a missed opportunity for CPAP, and the barriers and facilitators of CPAP utilization.

Results: 167 preterm neonates were reviewed from July to November 2021 and analyzed. 56 of these children (33.5% [95% CI 59.0% - 73.2%]) missed the opportunity to receive NCPAP. Twenty key informants were interviewed from September to October 2021. Facilitators of NCPAP use reported were: i) training of health workers, ii) availability of NCPAP machines, iii) KNH being a referral hospital and conditions of referrals, iv) global evidence that NCPAP use is beneficial, v) development of technology. Barriers to NCPAP use were mainly: i) inadequate number of NCPAP machines, ii) inadequate training and mentorship, iii) inadequate and inappropriate size of NCPAP consumables, iii) staff shortage, and iv) long servicing turnaround time, v) long cleaning turnaround time, vi) infrastructure challenges and vii) insufficient utilities.

Conclusion: Proportion of the missed opportunity for NCPAP was found to be high (33.5%). Barriers to NCPAP use were related to medical products and technologies, health workforce related challenges, and service delivery. We recommend the provision of more NCPAP machines, human resource support, frequent mentorship, infrastructure improvement, adequate and appropriate size of consumables, and promotion of family-centered care for the quality-of-care improvement.

Key words: Preterm neonate, Respiratory Distress Syndrome, Continuous Positive Air Pressure, Missed opportunity.

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3 **Study strengths and limitations**

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- 6 ➤ This study ensured a fairly accurate representation of NCPAP users in Kenyatta National
- 7 Hospital. We involved NCPAP users from different cadres to gain deeper understanding of the
- 8 facilitators and barriers to CPAP use.
- 9 ➤ This study will improve the quality of care for preterm infants.
- 10 ➤ The limitation of this study is that the enrollment of the preterm neonates in terms of gestational
- 11 age was based on Ballard's score done by the admitting clinician.
- 12 ➤ Recall bias for key informants may have occurred given certain answers required recall,
- 13 however they were given ample time to answer questions.
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BACKGROUND

The first twenty-eight (28) days of life has the highest chance of death in a lifetime. Globally 1/3 of all neonates die on the first day while three-quarters ($\frac{3}{4}$) die in only the first 7 days. A child born in sub-Saharan Africa (SSA) and Asia has a 20 times higher risk of death than in Australia and New Zealand. [1-3].

Premature and small for gestational age neonates have a fifteen times higher risk of death than other neonates, [2, 4]. Roughly 15 million infants are born prematurely annually; respiratory complications kill more than one million neonates, [4, 5]. Eighty percent (80%) of neonatal deaths in Africa are estimated to be caused by the high number of preterm births and its complications, [2]. In Kenya 2018, the neonatal mortality rate (NMR) was at 19.6/1000 live births, mostly due to prematurity complications 28 % and intrapartum-related complications 29%, [6]. In a study conducted in 2013 from five Kenyan hospitals, 38% of admissions were low birth weight infants with a 68% mortality rate, [7]. At Kisii Teaching and Referral Hospital, Kenya in 2015, RDS was the common reason for admission for preterm neonates at 56.6% with 73.15% of the overall deaths caused by RDS, [8]. KNH was found to have the highest prevalence of preterm births at 18.3% in the maternity unit in 2014 compared to World Health Organization (WHO) estimates,[9] and in 2018 overall neonatal mortality rate due to prematurity complication in KNH was 87.5% mostly likely due to lack of respiratory support,[10].

CPAP tends to reduce RDS mortality and the need for mechanical ventilation by almost a half. In lower and middle-income countries (LMICs); mechanical ventilation, surfactant, and CPAP are not easily accessible to every preterm infant in need and may be the case in Kenya, [11]. There have been a lot of efforts in limited settings to scale up NCPAP use by using improvised and low-cost bubble NCPAP machines to improve neonatal survival, [12, 13]. Despite improvised CPAP being a promising track in LMICs, there are still barriers to NCPAP implementation, [12, 14, 15]. A slow reduction in neonatal mortality has been observed worldwide thus WHO strongly recommended the use of CPAP in preterm infants. Focusing on effective intervention for RDS would decrease neonatal mortality in LMICs, [16]. Missed opportunity for CPAP in developed countries would mean those who met criteria for CPAP, but other interventions were done instead; like mechanical ventilation, [17]. In LMICs, the missed opportunity for CPAP is common due to CPAP unavailability or infrastructure constraints among others, [15, 18]. A study done in KNH by Nganga et al, in 2016 revealed that 56.9% of preterm infants were eligible for CPAP but did not get it, the reasons behind this were not captured in this study. Missed opportunities in KNH remain unclear with gaps that limit the understanding of what could be the reasons behind a missed opportunity for CPAP, [19]. This study aimed to find out the proportion and factors associated with a missed opportunity for CPAP in preterm infants admitted in the newborn unit, KNH.

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METHODS

Study design

A hospital-based cross-sectional study employed interactive explanatory concurrent mixed methods (qualitative and quantitative methods). The quantitative approach determined the proportion of missed opportunities for CPAP in preterm neonates admitted in NBU, KNH from July to November 2021 while the qualitative approach explored the barriers and facilitators of CPAP utilization in the newborn unit, KNH from September to October 2021. This mixed method approach helped us to understand the NCPAP missed opportunities in-depth and solutions to the NCPAP use barriers. Written informed consent were thought from each participant enrolled.

Study Population and Setting

This study was carried out at KNH. We included eligible preterm neonates < 37 weeks GA with moderate respiratory distress (SAS 4-6) within 48 hours of life and those who met the inclusion criteria for prophylactic CPAP as demonstrated in Figure 1. We conducted in-depth interviews with a representative sample of key informants who deal with NCPAP daily at KNH from the newborn unit, procurement, and biomedical engineering departments and these are neonatologists, neonatal fellows, pediatric registrars, medical officers, nurses, equipment nurse, procurement officer, and biomedical engineer, see **Figure S1 and S2**.

KNH is a public, level 6 referral hospital in Kenya. It serves as the teaching hospital of the University of Nairobi. KNH provides specialized tertiary health services for both adults and children in Kenya. On average, approximately 1200 neonates are admitted to NBU annually from the KNH labor ward, maternity theatre, post-delivery wards and referrals from other facilities.

Sampling

Quantitative: the sample size was determined by: Using a study in KNH, 56.9% did not get CPAP despite being eligible, using Fisher’s Formula to get our sample size with the significance of 7.5%.

$$n = \frac{z^2 p(1 - p)}{d^2} = 167$$

Estimated sample size (n) = 167 patients

z= standard normal deviate for 95% CI (1.96).

p= 56.9% (Nganga et al showed 56.9% neonates did not get CPAP (19).

d= the desired level of precision set at 7.5%.

In the same study, forty-seven infants met the criteria for prophylactic CPAP while fifty-five had SAS 4-6, so using a stratified sampling technique we aimed to balance 2 subpopulations (76 for the prophylactic CPAP group and 91 for those who developed RDS (SAS 4-6).

Qualitative: Participants were approached by the principal investigator and research assistant using purposive sampling, twenty key informants were selected and projected to reach saturation based on a study by Morse et al, [20] whereby no new information emerged from additional participants.

Data collection

This study was conducted from July to November 2021. Qualitative arm, participants were approached by the principal investigator and research assistant using purposive sampling. Twenty key informants were selected to reach saturation, 18 of them had face-to-face interviews and 2 had zoom meetings which were recorded with consent. Those that consented voluntarily were included in the study. No participant refused to participate or dropped-out. The data were collected using open guided interviews by the principal investigator and research assistant who were all practicing health care workers and had used NCPAP machines in training and work. Both were females and had received training in conducting in-depth interviews. No other person was present during the interview sessions. These were audio recorded by handheld tape recorder in addition to the field notes taken during interviews and noted when data was saturated. The sessions were recorded with consent and it took approximately 20 minutes for each participant. The interview guide (**figure 1**) was pilot tested and interviews were conducted in English and all researchers were fluent in that particular language. Key informants were informed that if they wished to express their views in Swahili, they would be given chance to do so. However, they were all comfortable and expressed their views in English. We did not return transcripts to the participants or repeat interviews.

Data Analysis

The data from the questionnaire were exported and cleaned in Excel, coded, and analyzed using STATA. Descriptive analysis were performed to determine proportions in all variables. These were summarized into frequency tables and charts. The Proportion of missed opportunity was computed by the number of infants who missed the chance to CPAP with the total number of eligible preterm infants as a denominator and was converted to a percentage (%) at a 95% confidence interval. For qualitative analysis, A hybrid approach to data analysis was employed: deductive based on our conceptual framework developed from the literature review; and an inductive approach, for which we were open to new themes that emerged during data collection. Audio recordings from IDIs were transcribed verbatim by the independent transcriber (anthropologist and a population studies researcher) and the research team. NVIVO software version 12 was utilized for data management. This transcription happened in a maximum period of one week after the recordings and analysis were conducted -guided by the thematic approach. The findings were aggregated, coded progressively, and line-by-line read to identify central themes. The central themes were revised to identify sub-themes, reports abstracted to findings, and these findings were presented in the form of direct quotations from the responses of participants.

Patient and public involvement statement

No involvement of the public or patients in the design or conduction of this study.

RESULTS

Quantitative results

167 preterm neonates were analyzed. Seventy-six of them met the criteria for prophylactic CPAP and 91 had Silverman Anderson Score (SAS) between four and six. Eighty-eight (52.7%) were male and the majority of neonates were between 28-32 GA weeks at 63(37.7%).

Table 1: Characteristics of the Preterm infants with RDS.

		Frequency (<i>n</i> =167)	Percent	Mean (SD)
Sex	Male	88	52.7	
	Female	79	47.3	
Birth weight	Median (IQR)			1391.4 (468.4)
	1300.0 (1050.0 – 1700.0)			
	ELBW (≤1000)	33	19.8	850.9 (112.6)
	VLBW (1001 – 1500)	82	49.1	1233.0 (140.0)
	LBW (1501 – 2500)	51	30.5	1970.2 (280.5)
Gestation age	>2500	1	0.6	2510 (-)
	Median(IQR)			
	30.0 (28.0 – 34.0)			
	<28 weeks	24	14.4	26.2 (0.7)
	28 to <32 weeks	63	37.7	29.1 (0.9)
Mode of delivery	32 to <34 weeks	32	19.2	32.9 (0.3)
	34 to <37 weeks	48	28.7	34.8 (0.8)
	SVD	86	51.5	
Gestation	CS	81	48.5	
	Single	146	87.4	
	Twin	17	10.2	
	Triplet	4	2.4	

Table 2 shows all neonates enrolled. The proportion of missed opportunity for CPAP was found to be 33.5% [95% CI 26.8% - 41.0%] (n=56). The majority of them got NCPAP at 66.5 % [95% CI 59.0% - 73.2%] (n=111). **Table 3 and (Table S1)** shows two subpopulations, the prophylactic CPAP group and those who had Silverman Anderson Score 4-6 that we aimed to enroll using stratified sampling technique. Thirty-four (44.7%) [95% CI 34.1% - 55.9%] in the prophylactic group missed opportunity for CPAP compared to (24.2%) [95% 16.5% - 33.9%] n=22 in SAS group.

Table 2: All preterm neonates enrolled

		Frequency (<i>n</i> =167)	Percent	95% CI
CPAP management	Yes	111	66.5	59.0% - 73.2%
Missed CPAP	No	56	33.5	26.8% - 41.0%
Total		167	100	

Table 3: Prophylactic CPAP group ((1000-1300g or 28-32 weeks)

		Frequency (<i>n</i> =76)	Percent	95% CI
CPAP management	Yes	42	55.3	44.1% - 65.9%
	No	34	44.7	34.1% - 55.9%
Total		76	100	

Qualitative results

We conducted 20 key informant interviews among different cadres working in NBU, biomedical engineering, and procurement departments. The majority were females at 55% and nurses at 45%. Average years of experience was 4 years in their respective departments and the average age was 38.9 years with the oldest being 56 years old and the youngest 27 years of age.

Table 4: Demographic characteristics of the key informant interviews.

Demographic characteristics	Number (n)	Percentage (%)
Neonatologists	2	10
Neonatology fellows	1	5
Paediatric registrars	3	15
Medical officers	2	10
Nurses	9	45
Maintenance engineers	1	5
Procurement officers	1	5
Equipment nurse	1	5
Women	11	55
	Median(IQR)	
Age in years	38.9 (29-40)	
Years of experience in the respective departments	4(3-10)	
Years of experience with CPAP usage	3(2-5)	

Benefits of CPAP

CPAP use was reported to be beneficial, reduces mortality, especially in preterm neonates, and helps to move away from invasive ventilation as a global recommendation. NCPAP doesn't have technical challenges compared to invasive mechanical ventilation. **Figure 1.**

Reasons associated with missed opportunities for CPAP

Although participants highlighted that CPAP is beneficial, there were challenges associated with CPAP use. Several barriers were mentioned to CPAP use namely; (1) the inadequate number of NCPAP machines. (2) Inadequate and inappropriate size of NCPAP accessories especially for extremely preterm neonates. (3) Inadequate training among users leads to a lack of confidence and competency to start CPAP. (4) Lack of mentorship on CPAP usage. (5) Lack of enough infrastructure to facilitate its use as well as insufficient utilities like oxygen points. (6) Staff shortage especially for monitoring and cleaning CPAP equipment after use. **Figure 1.**

Inadequate number of NCPAP machines

This was highlighted as the major barrier to CPAP use, the inadequate number of CPAP machines because the unit is a referral hospital and thus receives many preterm neonates in need of NCPAP machines and so the numbers in need might outweigh the available machines. When the babies are many and the CPAP machines are few, the SAS, age, and condition of the baby are used to determine which baby to start on CPAP using clinical judgment, and thus it is given to the baby who will benefit most.

“I have encountered that experience several times, it is an everyday encounter, no CPAP. Actually when you plan as a doctor for CPAP, you just write for CPAP when available because it is not available at that given time, yeah.” **Paediatric Registrar, DF01**

Faulty CPAP and servicing turnaround time.

It was noted throughout interviews that some NCPAP machines might be faulty and need outsourced services. Their servicing might be prolonged or take some time to be repaired and even those that are repaired locally by KNH engineers might require external spare parts that need to be requested through procurement/supplier chain. This process takes long and some machines might not be in use for some time.

“There are machines that require outsourced services, we ask for this service and the procurement process; the servicing might take long., there are those machines that we service ourselves, but we still require parts, the same thing will happen. It is not necessarily a problem with the procurement but it can also be the supplier; you tell them bring this then the supplier tells you that there is no what.” **Biomedical engineer, M01.**

“All the machines are on service contract ..., the challenge might be follow up and probably even the supplier may take the advantage come and say am fixing this maybe there is that”. **Procurement officer, M01.**

Cleaning turnaround time.

It was noted that machines may be available but they have been in use and need cleaning and disinfecting after use. It was noted during interviews that; there is only one nurse in charge of equipment and part of his/her responsibilities is to clean and disinfect machines after use so that they can be available for the next use. However, over the weekend days or night duties the nurse in a particular room who needs to put the baby on NCPAP machine, has to spare time and disinfect the equipment to be able to use it. This might take some time due to a shortage of staff and this, in turn, delays the start of CPAP.

“There is one person who does cleanings of equipment's and it's not only CPAP only. So waiting time may be prolonged.” **Nurse, F01.** “It depends, if they have all been occupied then that becomes a problem, on the weekends, some CPAPs have not been cleaned or there is usually no one to clean them. So the nurse who is in a certain room, if you need CPAP, you need to clean CPAP, you see and it is very tedious because they are also doing other things.” **Medical officer, F01**

Inappropriate size of NCPAP accessories.

It was noted that consumables, mostly nasal prongs contribute to the missed opportunity for NCPAP. This is because KNH receives extremely preterm neonates that may not be able to use the same size of nasal prongs with the late preterm or a term neonate.

“ Sometimes we get extreme preterm neonates; so, you find that even the smallest size of prongs doesn't fit so you find that it is difficult delivering the pressure and oxygen, due to the fact that prongs keep moving out...” **Nurse, F05**

Inadequate NCPAP accessories

Consumables were also highlighted as not adequate. Moreover, some may get lost or punctured and no longer be able to deliver the pressure or oxygen needed. Therefore, consumables supply was said to be inconsistent since this is based on the general paediatric department budget.

“For intensive care unit set up, it should be independent to be able to have its own budget, its own procurement... So, all these are based on the general pediatrics department,.. we have always run out of supplies.” **Neonatologist, DM03**

Inadequate training and mentorship among users.

Lack of training and mentorship among the users' leads to a lack of confidence and competency to start CPAP among the HCWs. It was noted that knowing how the machine works is very crucial in starting CPAP timely and monitoring a patient on NCPAP, especially with new machines. However, it was highlighted that the majority of staff were trained on how to use NCPAP which made a difference with regards to competency and confidence in using and starting NCPAP compared to previous years where some of the health care workers had to learn from their co-

workers. Despite the training that helped in this regard, not all staff got that chance to be trained due to duty responsibilities...

“The other one is competency, if someone is not competent and confident about using it, they pass it over to the next shift person. So, you will write in the file, start CPAP but they will keep moving around hoping their shift can end and someone else can come and put it.” **Neonatology fellow, DF01**

Challenges around infrastructure and utilities

Lack of appropriate infrastructure to facilitate CPAP usage was highlighted by key informants, due to limited space where to put CPAP machines, some NCPAP machines specifically Vayu bubble CPAP need resuscitaires to be put on which might not be available or not enough. Sometimes babies might be sharing one incubator which becomes tricky to start NCPAP. For Pumani CPAP machines, it was noted that these types of NCPAP need space which might be a challenge in a room that has many admissions or patients.

“The other thing is even a bed, you may be told the baby is in incubator and putting CPAP in an incubator where babies are sharing an incubator is a challenge.” **Nurse, M03** “the most concerning challenge actually is the ports; the oxygen outlet ports because they are not enough.” **Nurse, F04**

Staff shortage

Challenges around human resources were highlighted. It was mentioned that the unit has one equipment nurse and so when he is not on duty like on weekends or at night, in case of CPAP machine need, the nurse has to clean it herself/himself, there may be resuscitation that is ongoing and this might lead to delay of CPAP initiation or missed opportunity for it. It was highlighted that the new bubble NCPAP machines that were brought into the units (Vayu and Pumani), do require extra nursing care by frequent checking if nasal prongs are in/out or checking the water levels to mention a few. Doing that with staff shortage becomes a challenge hence some patients may not be getting the right pressure and the oxygen required.

“In this unit we have staff shortage, so most of the time it is one or two people in the room and as we said CPAP is a form of respiratory support, you want to make sure your prongs are in, checking water levels are okay. So, we have instances where, you actually walk in the room and the nasal prongs are in the air... You can find one nurse nursing fifteen babies; will they have enough time to check out on everybody...” **Neonatology fellow, DF01**

The partnership between health care workers and caregivers on CPAP usage.

The majority of the participants cited that there was a need to improve the partnership between health care workers and caregivers. The reason is that caregivers are not part of this process of

initiating CPAP. Some would find their babies on CPAP and when the nasal prongs were off, they didn't know how to put them back or inform nurses.

“There is a discrepancy because we tend to be overwhelmed with the number of patients, we have ... and the caretakers who are also supposed ... to understand how a CPAP works because for example, seven babies on CPAP but there are also other babies who are not on CPAP, they may be even more critical than those ones ... so you have to work between informing the mothers about the CPAP and resuscitation...” **Nurse, F03**

Facilitators of NCPAP use.

Since KNH is a referral facility that receives babies from peripheral facilities and varied conditions of babies, this has led to CPAP availability and provision in addition to global evidence of CPAP efficacy. CPAP training was highlighted as a factor that facilitated NCPAP use and competency among the users. **Figure 1.**

Training of health workers

Training which equips health workers with the knowledge of CPAP use was highlighted as an important factor that facilitated NCPAP utilization by increasing competency and confidence hence successful initiation, monitoring, and weaning off NCPAP machines.

“... we now have an induction program which includes respiratory support that includes CPAP, mechanical ventilation for new doctors rotating in the unit have to undertake...” **Nurse, M03**

Mentorship among the health care providers.

Mentorship which promotes CPAP use especially when new machines are being introduced in the unit was highlighted to prevent delay in CPAP initiation and prevent a negative approach toward new NCPAP machines in the unit.

“So, that acceptance of change is also an issue, so that is why we put the mentorship program so that people don't have negative attitude towards a certain machine before they even try it... These new ones they keep slipping off more frequently especially the Pumani, securing the nasal prongs is still a problem. The bubble CPAP you have to keep checking water and adding which the other CPAP machine doesn't have. These addition roles of these machines make some people shy away from them.” **Neonatology fellow, DF01**

Global evidence

The Staff thought that global evidence in terms of NCPAP efficacy and reduction in mortalities did facilitate its use in KNH newborn unit.

“Okay, there is global evidence to less push for ventilating babies, CPAP has been shown to be beneficial and with that kind of data worldwide and also within Africa, the move is now towards CPAP and advocate for that.” **Neonatologist, DM01**

KNH is a referral hospital

Kenyatta national hospital is a national referral hospital that does receive babies from peripheral facilities as well as KNH labor ward and theater. This labor ward receives high-risk deliveries including premature deliveries among other obstetric emergencies. The majority of admissions do need advanced care or respiratory support, and this has facilitated NCPAP use in the unit due to the condition of admissions on daily basis.

“We admit babies from all over the country...so they all refer babies here and that is what led to us having the CPAP machines here because it is now basically the population of babies born in the whole country.” **Nurse, M01**

When asked if the MOH or a sponsor wants to offer this unit CPAP support, what type of support would you ask for? This was asked to try and understand the solutions to the mentioned challenges on NCPAP use and below are themes that arose on solutions to barriers on NCPAP use. **Figure 1.**

DISCUSSION

Our study points out the proportion of the missed opportunity for NCPAP of preterm neonates admitted to NBU, KNH, and describes barriers and facilitators of NCPAP use from the key informants that deal with NCPAP use.

The proportion of missed opportunities for NCPAP was 33.5%, this was higher compared to a prospective study done in Malawi, [21]. Nigerian health facilities survey on accessible respiratory support showed oxygen to be the commonest available respiratory support at almost thirty-eight percent (38%) and 28% of the fifty-four facilities surveyed did not have any form of NCPAP machines, [13]. This shows that we still have missed opportunities for NCPAP in the region. Nganga et al 2016 found that 56.9% of two hundred and six (206) preterm neonates that were admitted in the Newborn unit, KNH didn't receive NCPAP, despite being eligible, [19]. This shows an improvement of 23.4% reduction in NCPAP missed opportunities in the Newborn unit, KNH five years later. The contribution to this reduction could be explained by an increase in the number of NCPAP machines, staff training among others. An improvement was also seen at Nakuru county referral hospital, Kenya in CPAP scale up from 2% in 2016-2017 to seventeen percent of CPAP use in 2018 after the quality upgrading initiative, [22].

Despite the NCPAP missed opportunities, the participants mentioned that; CPAP is beneficial and helps in the reduction of neonatal mortality and the need for invasive mechanical ventilation. In India, CPAP use was perceived as an important intervention that helps in the reduction of neonatal mortality, [23]. This was comparable with results from four observational studies from a systematic review done to find out the efficacy and safety of CPAP in LMICs, [24]. A non-

randomized control study from Malawi showed a twenty-seven percent (27%) improvement in survival of neonates with RDS after the introduction of NCPAP versus oxygen therapy, [25]. This was consistent with a prospective pre-and post-intervention study using CPAP in Nicaragua that showed mortality reduction by a half and intubation reduction by 33%, [26]. A randomized control trial done in Tanzania showed a 52% lower risk of death with the BCPAP group, [27]. A similar study in Kenya showed survival rates of 61% vs. 85% for Pre-BCPAP and post low cost BCPAP group respectively, [28]. On the other hand, a systematic review in 2020 showed clinical improvement and mechanical ventilation reduction without change in mortality by BCPAP use, [29]. In contrast, the BCPAP failure rate in an Indian study was higher at 42% in the RDS group compared to other CPAP indications studied including meconium aspiration syndrome, [30]. The similar remarkable results were seen from LMICs with improvised NCPAP use, [14, 28, 31, 32, 33].

In our study, key informants believed that infrastructure challenges, CPAP consumables, and inappropriate sizes of nasal prongs especially for preterm neonates hinder CPAP use. These findings are similar to a systematic review from seventeen (17) studies done in SSA that showed unavailability of CPAP machines, and shortage of consumables were recurrently stated barriers to bubble CPAP implementation, [14]. A related study done in Kenya found the same barriers to using CPAP to be infrastructure-related challenges, inadequate and inappropriate size of consumables mainly nasal prongs, and this happened mostly after completion of donor's implementation, [15]. Another study in India showed that lack of enough equipment and consumables changed health care workers' perception of CPAP quality and effectiveness, [23]. Therefore, these are challenges faced by low limited settings where mostly NCPAP machines are donated without a clear plan of a constant supply of consumables or maintenance of such equipment, thus a need for young inventors of new technologies as well as training of biomedical engineers in these settings for the sustainability of this essential equipment, [34]. Timely maintenance of NCPAP machines and consumables was highlighted as a challenge by our key informants, this was in-line with a study in Ghana, [35].

In addition, our findings showed that sometimes CPAP machines and consumables might be available, however, staff shortage might delay its initiation and monitoring challenges. Health workers in Malawi recently expressed CPAP initiation and monitoring challenges they face especially when there is a shortage of cover, this may lead to delayed CPAP initiation and poor monitoring, [18]. Overwhelming of health care workers by many patients in India was thought to lead to poor neonatal outcomes and mortalities without close monitoring, [23]. This was in agreement with a study in Kenya, [36]. A systematic review in SSA did show workloads in the units affects the quality of care and training opportunities, [14]. Nevertheless, there is a need to think about world health organization recommendations on task shifting which would help in improving access to newborn health interventions in such staff shortage situations,[37,38].

Our study participants believed that global evidence of CPAP efficacy enabled its use. This was commonly mentioned in different studies, [39- 41]. On the other hand, the barriers to NCPAP use

were alleviated by promising outcomes of CPAP in a recent Kenyan study, [15]. Our findings also underlined that; staff training facilitated NCPAP use, this is in-line with findings from an observational study from a rural Ugandan neonatal ICU, [42]. In Malawi, the competency in using CPAP increased from thirty-two percent to ninety-seven percent, and CPAP use improved by sixteen percent after the peer mentorship program, [30]. A similar study from AIC Kijabe Hospital Nursery, Kenya showed higher survival to discharge rates, the adequate training of staff after the introduction of CPAP which concurred with the hiring of a clinical officer likely enabled staff to initiate CPAP safely, and hence favorable outcomes, [28]. A related study in Kenya on effective training of trainers after NCPAP implementation showed promising results on successful initiation of CPAP by nurses, [34]. The health partnership and international experts' upkeep on training schemes have been shown to improve CPAP uptake in the newborn care units from four different hospitals in Rwanda, [35]. On the other hand, insufficient training was mentioned as a barrier to NCPAP use, and hence frequent training/CMEs and mentorship was thought to play an important role in CPAP use by our study participants. Two studies in Rwanda and Ghana presented a challenge in the identification of eligible neonates after short training, [35, 43]. Carns et al, recently highlighted that training and mentorship do increase CPAP uptake, [44].

CONCLUSION

This study shows that progress has been made. There is a 23.4% reduction in NCPAP missed opportunities in the Newborn unit, KNH five years later (between 2016 and 2021). However, we still have missed opportunity for NCPAP at 33.5% [95% CI 59.0% - 73.2%] in NBU, KNH. Missed opportunity for prophylactic group and SAS group was found to be 44.7 (34.1% - 55.9%) and 24.2 (16.5% - 33.9%) respectively.

Barriers to NCPAP use were related to medical products and technologies, health workforce challenges, and service delivery. Solutions highlighted by the key informants are: provision of more NCPAP machines, Human resource support, frequent training/CMEs/mentorship, infrastructure improvement, adequate and appropriate size of consumables, promotion of family-centered care, and engagement of the equipment's manufacturer. Future CPAP scale-up should consider the provision of more NCPAP machines, human resource support, frequent training/CMEs/mentorship, infrastructure improvement, the adequate and appropriate size of consumables, and promotion of family-centered care. This study was done when new NCPAP machines were being introduced in the unit and therefore, a similar study in the future including caregivers and focus group discussions would help in quality care improvement.

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No Conflict of interest to declare.

Contributors

PK coordinated the study, analyzed the data, prepared the manuscript and approved the final manuscript as submitted. She took over as Principal Investigator of the study prior to the commencement of data collection and coordinated all aspects of the project thereafter. **FM and DM** analyzed the data, prepared the manuscript and approved the final manuscript as submitted.

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Patient and public involvement

No involvement of the public or patients in the design or conduction of this study

Patient consent for publication

Not applicable

Ethics approval

The project was approved by the Kenyatta National Hospital/ university of Nairobi ethics research committee (P206/03/2021).

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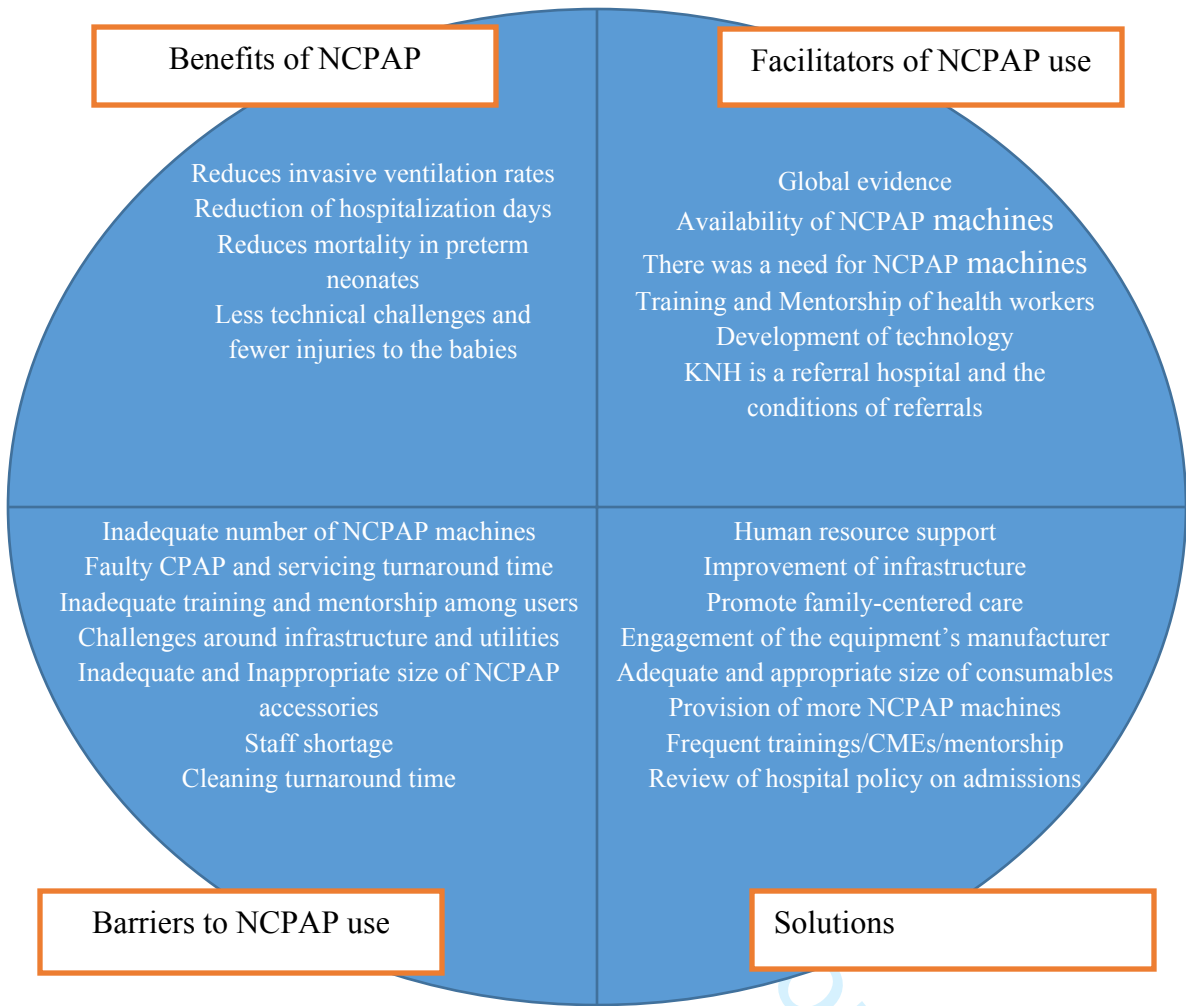


Figure 1. Major themes on Benefits, Facilitators, Barriers of NCPAP use and Solutions

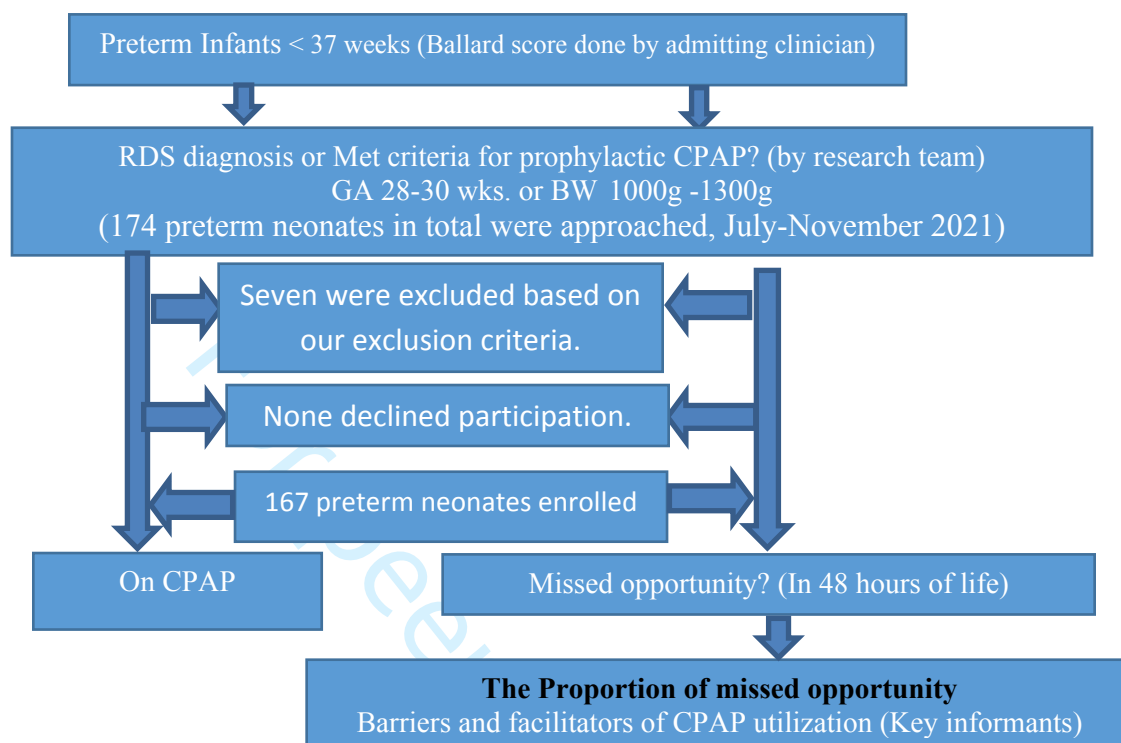


Figure S1. Study summary for quantitative study

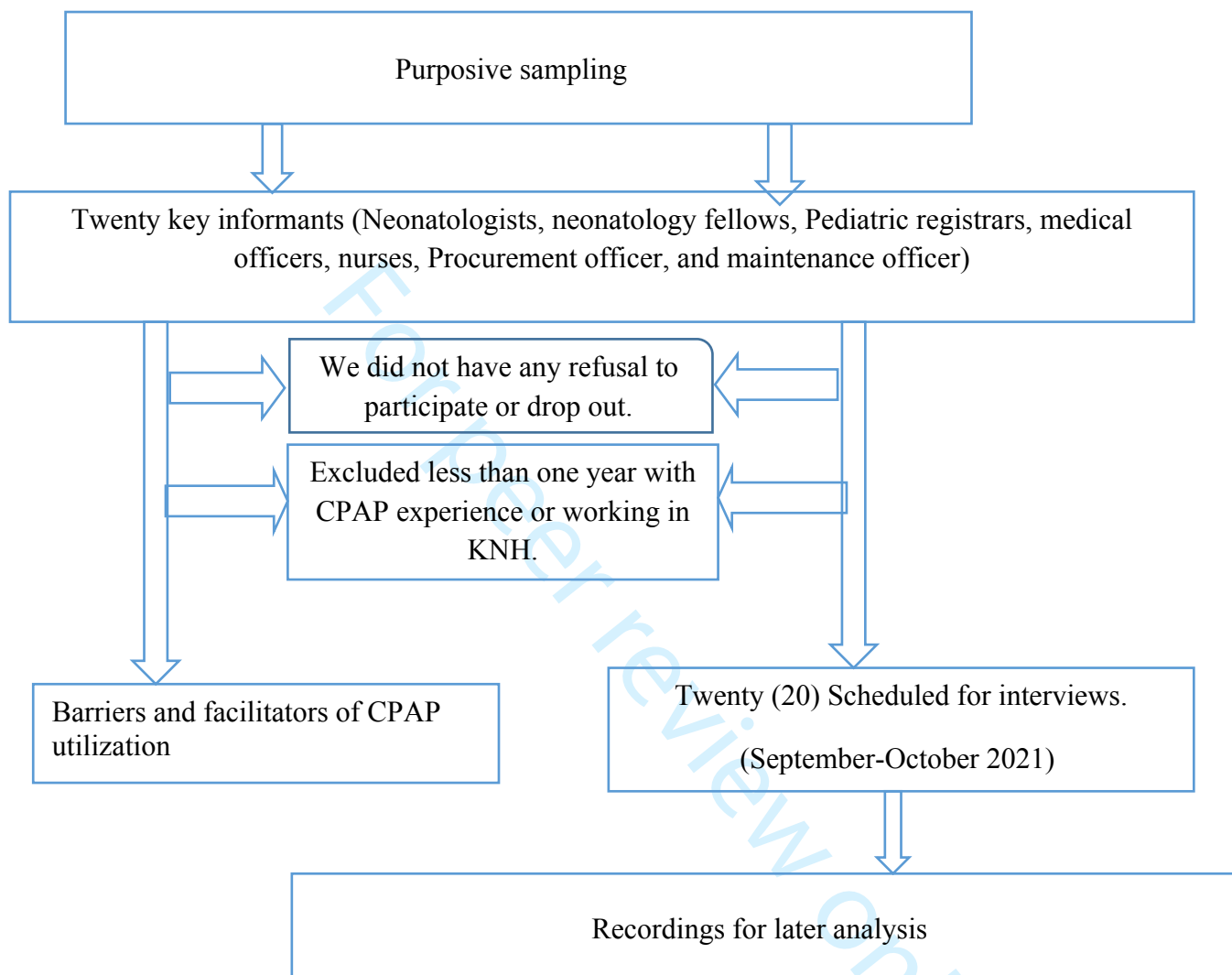


Figure S2. Study summary for qualitative study.

Table S1: SAS group (4-6) (exclusion of those in the prophylactic group).

		Frequency (<i>n=91</i>)	Percent	95% CI
CPAP management	Yes	69	75.8	66.1% - 83.5%
	No	22	24.2	16.5% - 33.9%
Total		91	100	

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Missed opportunity for Nasal Continuous Positive Airway Pressure in preterm neonates admitted at tertiary level hospital, New Born Unit in Kenya- A mixed method study.

ABSTRACT

Objectives: To determine the proportion of preterm neonates admitted to the newborn unit at Kenyatta National Hospital (KNH) with a missed opportunity for Nasal continuous positive pressure (NCPAP), and to determine the barriers and facilitators of NCPAP utilization.

Design and setting: This was a hospital-based cross-sectional study that employed interactive explanatory concurrent mixed methods.

Participants: Preterm neonates (<37 weeks) within 48 hours of life who met the criteria for NCPAP. The key informants were mainly; different staff cadres from the newborn unit, procurement officer, and a biomedical engineer.

Primary and secondary outcome measure: The proportion of preterm infants admitted to the newborn unit with a missed opportunity for NCPAP, and the barriers and facilitators of NCPAP utilization.

Results: 167 preterm neonates were reviewed from July to November 2021 and analyzed. 56 of these children (33.5% [95% CI 59.0% - 73.2%]) missed the opportunity to receive NCPAP. Twenty key informants were interviewed from September to October 2021. Facilitators of NCPAP use reported were: i) training of health workers, ii) availability of NCPAP machines, iii) KNH being a referral hospital and conditions of referrals, iv) global evidence that NCPAP use is beneficial, v) development of technology. Barriers to NCPAP use were mainly: i) inadequate number of NCPAP machines, ii) inadequate training and mentorship, iii) inadequate and inappropriate size of NCPAP consumables, iii) staff shortage, and iv) long servicing turnaround time, v) long cleaning turnaround time, vi) infrastructure challenges and vii) insufficient utilities.

Conclusion: Proportion of the missed opportunity for NCPAP was found to be high (33.5%). Barriers to NCPAP use were related to medical products and technologies, health workforce related challenges, and service delivery. We recommend the provision of more NCPAP machines including supporting infrastructure and appropriate consumables, human resource support, frequent training and mentorship on NCPAP use.

Keywords: Preterm neonate, Respiratory Distress Syndrome, Continuous Positive Air Pressure, Missed opportunity.

Study strengths and limitations

- This study ensured a fairly accurate representation of NCPAP users in Kenyatta National Hospital. We involved NCPAP users from different cadres to gain deeper understanding of the facilitators and barriers to NCPAP use.
- The limitation of this study is that the enrollment of the preterm neonates in terms of gestational age was based on Ballard's score done by the admitting clinician.
- Recall bias for key informants may have occurred given certain answers required recall; however, they were given ample time to answer questions.

BACKGROUND

The first twenty-eight days of life has the highest chance of death in a lifetime [1]. Globally 1/3 of all neonates die on the first day while three-quarters ($\frac{3}{4}$) die in only the first 7 days [2,3]. A child born in sub-Saharan Africa (SSA) and Asia has a 20 times higher risk of death than in Australia and New Zealand [1,2,4].

Premature and small for gestational age neonates have a fifteen times higher risk of death than other neonates [2, 5]. Roughly 15 million infants are born prematurely annually; respiratory complications kill more than one million neonates [5, 6]. Eighty percent (80%) of neonatal deaths in Africa are estimated to be caused by the high number of preterm births and its complications [2]. Respiratory Distress Syndrome (RDS) occurs commonly with preterm neonates and was found to be associated with higher mortalities in African nations [2,7,8,9]. In Kenya 2018, the neonatal mortality rate (NMR) was at 19.6/1000 live births, mostly due to prematurity complications 28 % and intrapartum-related complications 29% [10]. In a study conducted in 2013 from five Kenyan hospitals, 38% of admissions were low birth weight infants with a 68% mortality rate [11]. At Kisii Teaching and Referral Hospital, Kenya in 2015, RDS was the common reason for admission for preterm neonates at 56.6% with 73.15% of the overall deaths caused by RDS [12]. KNH was found to have the highest prevalence of preterm births at 18.3% in the maternity unit in 2014 compared to World Health Organization (WHO) estimates [13] and in 2018 overall neonatal mortality rate due to prematurity complication in KNH was 87.5% mostly likely due to lack of respiratory support [14].

Continuous Positive Airway Pressure (CPAP) tends to reduce RDS mortality and the need for mechanical ventilation by almost a half [15]. In lower and middle-income countries (LMICs); mechanical ventilation, surfactant, and CPAP are not easily accessible to every preterm infant in need and may be the case in Kenya [15]. There have been a lot of efforts in limited settings to scale up NCPAP use by using improvised and low-cost bubble NCPAP machines to improve neonatal survival [16, 17]. Despite improvised CPAP being a promising track in LMICs, there are still barriers to NCPAP implementation [16, 18, 19]. A slow reduction in neonatal mortality has been observed worldwide thus WHO strongly recommended the use of CPAP in preterm infants [20]. Focusing on effective intervention for RDS would decrease neonatal mortality in LMICs [21].

Missed opportunity for CPAP in developed countries would mean those who met criteria for CPAP, but other interventions were done instead; like mechanical ventilation [22]. In LMICs, the missed opportunity for CPAP is common due to CPAP unavailability or infrastructure constraints among others [19, 23]. A study done in KNH by Nganga et al, in 2016 revealed that 56.9% of preterm infants were eligible for NCPAP but did not get it, the reasons behind this were not captured in this study. Missed opportunities in KNH remain unclear with gaps that limit the understanding of what could be the reasons behind a missed opportunity for NCPAP [24]. This study aimed to find out the proportion and factors associated with a missed opportunity for NCPAP in preterm infants admitted in the newborn unit, KNH.

METHODS

Study design

A hospital-based cross-sectional study employed interactive explanatory concurrent mixed methods (qualitative and quantitative methods). The quantitative approach determined the proportion of missed opportunities for NCPAP in preterm neonates admitted in NBU, KNH from July to November 2021 while the qualitative approach explored the barriers and facilitators of NCPAP utilization in the newborn unit, KNH from September to October 2021. This mixed method approach helped us to understand the NCPAP missed opportunities in-depth and solutions to the NCPAP use barriers. Written informed consent were obtained from each participant enrolled.

Study Population and Setting

This study was carried out at KNH. We included eligible preterm neonates < 37 weeks GA with moderate respiratory distress (Silverman Anderson Score (SAS) 4-6) within 48 hours of life and those who met the inclusion criteria for prophylactic NCPAP according to the comprehensive newborn care protocols as demonstrated in Figure 1, [25]. Some neonates had unrecorded GA due to unknown LMP or unavailable first trimester ultrasound scan results, Ballards was done to clinically confirm GA by admitting Clinicians. RDS Severity depends on clinical signs and laboratory findings, SAS consists of 5 signs, it shows degree of respiratory severity, and helps in sorting out children who need respiratory support than others. Rescue CPAP is indicated when SAS is 4-6 indicating moderate respiratory distress [25, 26, 27], on the other hand, the prophylactic CPAP is indicated when preterm neonates have GA of 28-30 weeks or BW 1000-1300g [24].

We conducted in-depth interviews with a representative sample of key informants who deal with NCPAP daily at KNH from the newborn unit, procurement, and biomedical engineering departments and these are neonatologists, neonatal fellows, pediatric registrars, medical officers, bedside nurses, equipment nurse, procurement officer, and biomedical engineer, see **Figure S1 and S2**.

KNH is a public, level 6 referral hospital in Kenya. It serves as the teaching hospital of the University of Nairobi. KNH provides specialized tertiary health services for both adults and children in Kenya. On average, approximately 1200 neonates are admitted to Newborn Unit (NBU) annually from the KNH labor ward, maternity theatre, post-delivery wards and referrals from other facilities.

Sampling

Quantitative: the sample size was determined by: Using a study in KNH, 56.9% did not get CPAP despite being eligible, Using the Fisher's formula with a significance of 7.5%, the sample size is as follows:

$$n = \frac{z^2 p(1-p)}{d^2} = 167$$

Estimated sample size (n) = 167 patients
z= standard normal deviate for 95% CI (1.96).
p= 56.9% (Nganga et al showed 56.9% neonates did not get CPAP (19).
d= the desired level of precision set at 7.5%.

In the same study, forty-seven infants met the criteria for prophylactic CPAP while fifty-five had SAS 4-6, so using a stratified sampling technique we aimed to balance 2 subpopulations (76 for the prophylactic CPAP group and 91 for those who developed RDS (SAS 4-6).

Qualitative: Participants were approached by the principal investigator and research assistant using purposive sampling, twenty key informants were selected and projected to reach saturation based on a study by Morse et al, [28] whereby no new information emerged from additional participants.

Data collection

This study was conducted from July to November 2021. In the qualitative arm, participants were approached by the principal investigator and research assistant using purposive sampling. Twenty key informants were selected to reach saturation, 18 of them had face-to-face interviews and 2 had zoom meetings which were recorded with consent. Those that consented voluntarily were included in the study. No participant refused to participate or dropped-out. The data were collected using open guided interviews by the principal investigator and research assistant who were all practicing health care workers and had used NCPAP machines in training and work. Both were females and had received training in conducting in-depth interviews. No other person was present during the interview sessions. These were audio recorded by handheld tape recorder in addition to the field notes taken during interviews and noted when data was saturated. The sessions were recorded with consent and it took approximately 20 minutes for each participant. The interview guide (figure 1) was pilot tested and interviews were conducted in English and all researchers were fluent in that particular language, Key informants were informed that if they wished to express their views in Swahili, they would be given chance to do so. However, they were all comfortable and expressed their views in English. We did not return transcripts to the participants or repeat interviews.

Data Analysis

The data from the questionnaire were exported and cleaned in Excel, coded, and analyzed using STATA. Descriptive analysis was performed to determine proportions in all variables. These were summarized in frequency tables and charts. The Proportion of missed opportunity was computed by the number of infants who missed the chance to NCPAP with the total number of eligible preterm infants as a denominator and was converted to a percentage (%) at a 95% confidence interval.

For qualitative analysis, a hybrid approach to data analysis was employed: deductive based on our conceptual framework developed from the literature review; and an inductive approach, for which we were open to new themes that emerged during data collection. Audio recordings from IDIs were transcribed verbatim by the independent transcriber (anthropologist and a population studies researcher) and the research team. NVIVO software version 12 was utilized for data management. This transcription happened in a maximum period of one week after the recordings and analysis were conducted -guided by the thematic approach.

The findings were aggregated, coded progressively, and line-by-line read to identify central themes. The central themes were revised to identify sub-themes, reports abstracted to findings, and these findings were presented in the form of direct quotations from the responses of participants.

Patient and public involvement statement

No involvement of the public or patients in the design or conduction of this study.

RESULTS

Quantitative results

167 preterm neonates were analyzed. Seventy-six of them met the criteria for prophylactic NCPAP and 91 had Silverman Anderson Score (SAS) between four and six. Eighty-eight (52.7%) were male and the majority of neonates were between 28-32 gestational age (GA) weeks at 63(37.7%) as illustrated in Table 1.

Table 1: Characteristics of the Preterm infants with RDS.

		Frequency (<i>n</i> =167)	Percent	Mean (SD)
Sex	Male	88	52.7	
	Female	79	47.3	
Birth weight	Median (IQR)			1391.4 (468.4)
	1300.0 (1050.0 – 1700.0)			
	ELBW ($\leq$ 1000)	33	19.8	850.9 (112.6)
	VLBW (1001 – 1500)	82	49.1	1233.0 (140.0)
	LBW (1501 – 2500)	51	30.5	1970.2 (280.5)
Gestation age	>2500	1	0.6	2510 (-)
	Median(IQR)			
	30.0 (28.0 – 34.0)			
	<28 weeks	24	14.4	26.2 (0.7)
	28 to <32 weeks	63	37.7	29.1 (0.9)
Mode of delivery	32 to <34 weeks	32	19.2	32.9 (0.3)
	34 to <37 weeks	48	28.7	34.8 (0.8)
	SVD	86	51.5	
	CS	81	48.5	
Gestation	Single	146	87.4	
	Twin	17	10.2	
	Triplet	4	2.4	

Table 2 shows all neonates enrolled. The proportion of missed opportunity for CPAP was found to be 33.5% [95% CI 26.8% - 41.0%] (n=56). The majority of them got NCPAP at 66.5 % [95% CI 59.0% - 73.2%] (n=111). **Table 3 and (Table S1)** shows two subpopulations, the prophylactic NCPAP group and those who had Silverman Anderson Score 4-6 that we aimed to enroll using stratified sampling technique. Thirty-four (44.7%) [95% CI 34.1% - 55.9%] in the prophylactic group missed opportunity for NCPAP compared to (24.2%) [95% 16.5% - 33.9%] n=22 in SAS group.

Table 2: All preterm neonates enrolled

		Frequency (<i>n</i> =167)	Percent	95% CI
NCPAP management	Yes	111	66.5	59.0% - 73.2%
Missed NCPAP	No	56	33.5	26.8% - 41.0%
Total		167	100	

Table 3: Prophylactic CPAP group ((1000-1300g or 28-32 weeks)

		Frequency (<i>n</i> =76)	Percent	95% CI
NCPAP management	Yes	42	55.3	44.1% - 65.9%
	No	34	44.7	34.1% - 55.9%
Total		76	100	

Qualitative results

We conducted 20 key informant interviews among different cadres working in NBU, biomedical engineering, and procurement departments. The majority were females at 55% and nurses at 45%. Average years of experience was 4 years in their respective departments and the average age was 38.9 years with the oldest being 56 years old and the youngest 27 years of age as shown in Table 4.

Table 4: Demographic characteristics of the key informant interviews.

Demographic characteristics	Number (n)	Percentage (%)
Neonatologists	2	10
Neonatology fellows	1	5
Paediatric registrars	3	15
Medical officers	2	10
Nurses	9	45
Maintenance engineers	1	5
Procurement officers	1	5
Equipment nurse	1	5
Women	11	55
	Median(IQR)	
Age in years	38.9 (29-40)	
Years of experience in the respective departments	4(3-10)	
Years of experience with CPAP usage	3(2-5)	

Benefits of CPAP

NCPAP use was reported to be beneficial, reduces mortality, especially in preterm neonates, and helps to move away from invasive ventilation as a global recommendation. NCPAP does not have technical challenges compared to invasive mechanical ventilation. **Figure 1.**

Reasons associated with missed opportunities for CPAP

Although participants highlighted that CPAP is beneficial, there were challenges associated with NCPAP use. Several barriers were mentioned to NCPAP use namely; (1) the inadequate number of NCPAP machines (2) Inadequate and inappropriate size of NCPAP accessories especially for extremely preterm neonates (3) Inadequate training among users leading to a lack of confidence and competency to start NCPAP (4) Lack of mentorship on NCPAP usage (5) Lack of adequate infrastructure to facilitate its use as well as insufficient utilities like oxygen points (6) Staff shortage especially for monitoring and cleaning NCPAP equipment after use. **Figure 1.**

Inadequate number of NCPAP machines

This was highlighted as the major barrier to NCPAP use. The inadequate number of NCPAP machines was because the unit is a referral hospital and thus receives many preterm neonates in need of NCPAP machines and so the numbers in need might outweigh the available machines. When the babies are many and the NCPAP machines are few, the SAS, age, and condition of the baby are used to determine which baby to start on NCPAP using clinical judgment, and thus it is given to the baby who will benefit most.

“I have encountered that experience several times, it is an everyday encounter, no CPAP. Actually when you plan as a doctor for CPAP, you just write for CPAP when available because it is not available at that given time, yeah.” **Paediatric Registrar, DF01**

Faulty CPAP and servicing turnaround time.

It was noted throughout interviews that some NCPAP machines might be faulty and need outsourced services. Their servicing might be prolonged or take some time to be repaired and even those that are repaired locally by KNH engineers might require external spare parts that need to be requested through procurement/supplier chain. This process takes long and some machines might not be in use for some time.

“There are machines that require outsourced services, we ask for this service and the procurement process; the servicing might take long., there are those machines that we service ourselves, but we still require parts, the same thing will happen. It is not necessarily a problem with the procurement but it can also be the supplier; you tell them bring this then the supplier tells you that there is no what.” **Biomedical engineer, M01.**

“All the machines are on service contract ..., the challenge might be follow up and probably even the supplier may take the advantage come and say am fixing this maybe there is that”. **Procurement officer, M01.**

Cleaning turnaround time.

It was noted that machines may be available but they have been in use and need cleaning and disinfecting after use. It was noted during interviews that; there is only one nurse in charge of equipment and part of his/her responsibilities is to clean and disinfect machines after use so that they can be available for the next use. However, over the weekend days or night duties the nurse in a particular room who needs to put the baby on NCPAP machine, has to spare time to disinfect the equipment before use. This might take some time due to a shortage of staff and this, in turn, delays the start of CPAP.

“There is one person who does cleanings of equipment's and it's not only CPAP only. So waiting time may be prolonged.” **Nurse, F01.** “It depends, if they have all been occupied then that becomes a problem, on the weekends, some CPAPs have not been cleaned or there is usually no one to clean them. So, the nurse who is in a certain room, if you need CPAP, you need to clean CPAP, you see and it is very tedious because they are also doing other things.” **Medical officer, F01**

Inappropriate size of NCPAP accessories.

It was noted that consumables, mostly nasal prongs contribute to the missed opportunity for NCPAP. This is because KNH receives extremely preterm neonates that may not be able to use the same size of nasal prongs as late preterm or term neonates.

“ Sometimes we get extreme preterm neonates; so, you find that even the smallest size of prongs doesn't fit so you find that it is difficult delivering the pressure and oxygen, due to the fact that prongs keep moving out...” **Nurse, F05**

Inadequate NCPAP accessories

Consumables were also highlighted as not adequate. Moreover, some may get lost or punctured and no longer be able to deliver the pressure or oxygen needed. Therefore, consumables supply was said to be inconsistent since this is based on the general paediatric department budget.

“For intensive care unit set up, it should be independent to be able to have its own budget, its own procurement... So, all these are based on the general pediatrics department, we have always run out of supplies.” **Neonatologist, DM03**

Inadequate training and mentorship among users.

Lack of training and mentorship among the users' leads to a lack of confidence and competency to start NCPAP among the HCWs. It was noted that knowing how the machine works is very crucial in starting NCPAP timely and monitoring a patient on NCPAP, especially with new machines. However, it was highlighted that the majority of staff were trained on how to use NCPAP which made a difference with regards to competency and confidence in using and starting NCPAP compared to previous years where some of the health care workers had to learn from their co-workers. Despite the training that helped in this regard, not all staff got that chance to be trained due to duty responsibilities...

“The other one is competency, if someone is not competent and confident about using it, they pass it over to the next shift person. So, you will write in the file, start CPAP but they will keep moving around hoping their shift can end and someone else can come and put it.” **Neonatology fellow, DF01**

Challenges around infrastructure and utilities

Lack of appropriate infrastructure to facilitate NCPAP usage was highlighted by key informants, especially due to limited space. Some NCPAP machines, specifically Vayu bubble CPAP need resuscitaires to be put on which might not be available or not enough. Sometimes babies share a single incubator which becomes tricky to start NCPAP. For Pumani CPAP machines, it was noted that these types of NCPAP need space which might be a challenge in a room that has many admissions or patients.

“The other thing is even a bed, you may be told the baby is in incubator and putting CPAP in an incubator where babies are sharing an incubator is a challenge.” **Nurse, M03** “the most concerning challenge actually is the ports; the oxygen outlet ports because they are not enough.” **Nurse, F04**

Staff shortage

Challenges around human resources were highlighted. It was mentioned that the unit has one equipment nurse and so when he is not on duty like on weekends or at night, in case of NCPAP machine need, the nurse has to clean it herself/himself, there may be resuscitation that is ongoing and this might lead to delay of NCPAP initiation or missed opportunity for it. It was highlighted that the new bubble NCPAP machines that were brought into the units (Vayu and Pumani), do require extra nursing care by frequent checking if nasal prongs are in/out or checking the water levels to mention a few. Doing that with staff shortage becomes a challenge hence some patients may not be getting the right pressure and the oxygen required.

“In this unit we have staff shortage, so most of the time it is one or two people in the room and as we said CPAP is a form of respiratory support, you want to make sure your prongs are in, checking water levels are okay. So, we have instances where, you actually walk in the room and the nasal prongs are in the air... You can find one person nursing fifteen babies; will they have enough time to check out on everybody...” **Neonatology fellow, DF01**

The partnership between health care workers and caregivers on CPAP usage.

The majority of the participants cited that there was a need to improve the partnership between health care workers and caregivers. The reason is that caregivers are not part of this process of initiating NCPAP. Some would find their babies on NCPAP and when the nasal prongs were off, they didn't know how to put them back or inform nurses.

“There is a discrepancy because we tend to be overwhelmed with the number of patients, we have ... and the caretakers who are also supposed ... to understand how a CPAP works because for example, seven babies on CPAP but there are also other babies who are not on CPAP, they may be even more critical than those ones ... so you have to work between informing the mothers about the CPAP and resuscitation...” **Nurse, F03**

Facilitators of NCPAP use.

Since KNH is a referral facility that receives babies from peripheral facilities and varied conditions of babies, this has led to NCPAP availability and provision in line with global evidence of CPAP efficacy. CPAP training was highlighted as a factor that facilitated NCPAP use and competency among the users. **Figure 1.**

Training of health workers

Training which equips health workers with the knowledge of NCPAP use was highlighted as an important factor that facilitated NCPAP utilization by increasing competency and confidence in the successful initiation, monitoring, and weaning off NCPAP machines.

“... we now have an induction program which includes respiratory support that includes CPAP, mechanical ventilation for new doctors rotating in the unit have to undertake...” **Nurse, M03**

Mentorship among the health care providers.

Mentorship which promotes NCPAP use especially when new machines are being introduced in the unit was highlighted to prevent delay in NCPAP initiation and prevent a negative approach toward new NCPAP machines in the unit.

“So, that acceptance of change is also an issue, so that is why we put the mentorship program so that people don’t have negative attitude towards a certain machine before they even try it... These new ones they keep slipping off more frequently especially the Pumani, securing the nasal prongs is still a problem. The bubble CPAP you have to keep checking water and adding which the other CPAP machine doesn’t have. These addition roles of these machines make some people shy away from them.” **Neonatology fellow, DF01**

Global evidence

The Staff thought that global evidence in terms of NCPAP efficacy and reduction in mortalities did facilitate its use in KNH newborn unit.

“Okay, there is global evidence to less push for ventilating babies, CPAP has been shown to be beneficial and with that kind of data worldwide and also within Africa, the move is now towards CPAP and advocate for that.” **Neonatologist, DM03**

KNH is a referral hospital

Kenyatta national hospital is a national referral hospital that does receive babies from peripheral facilities as well as KNH labor ward and theater. This labor ward receives high-risk deliveries including premature deliveries among other obstetric emergencies. The majority of admissions do need advanced care or respiratory support, and this has facilitated NCPAP use in the unit due to the condition of admissions on daily basis.

“We admit babies from all over the country...so they all refer babies here and that is what led to us having the CPAP machines here because it is now basically the population of babies born in the whole country.” **Nurse, M01**

When asked if the Ministry of Health (MOH) or a sponsor wants to offer this unit CPAP support, what type of support would you ask for? This was asked to try and understand the solutions to the mentioned challenges on NCPAP use and below are themes that arose on solutions to barriers on NCPAP use. **Figure 1.**

DISCUSSION

Our study points out the proportion of the missed opportunity for NCPAP of preterm neonates admitted to NBU, KNH, and describes barriers and facilitators of NCPAP use from the key informants.

The proportion of missed opportunities for NCPAP was 33.5%, this was higher compared to a prospective study done in Malawi [29]. Nigerian health facilities survey on accessible respiratory support showed oxygen to be the commonest available respiratory support at almost thirty-eight percent (38%) and 28% of the fifty-four facilities surveyed did not have any form of NCPAP machines [17]. This shows that we still have missed opportunities for NCPAP in the region. Nganga et al 2016 found that 56.9% of two hundred and six (206) preterm neonates that were admitted in the Newborn unit, KNH didn't receive NCPAP, despite being eligible [24]. This shows a 23.4% reduction in NCPAP missed opportunities in the Newborn unit, KNH five years later. The contribution to this reduction could be explained by an increase in the number of NCPAP machines, staff training among others. An improvement was also seen at Nakuru county referral hospital, Kenya in CPAP scale up from 2% in 2016-2017 to seventeen percent of CPAP use in 2018 after the quality upgrading initiative [30].

Despite the NCPAP missed opportunities, the participants mentioned that; CPAP is beneficial and helps in the reduction of neonatal mortality and the need for invasive mechanical ventilation. In India, CPAP use was perceived as an important intervention that helps in the reduction of neonatal mortality [31]. This was comparable with results from four observational studies from a systematic review done to find out the efficacy and safety of CPAP in LMICs [32]. A non-randomized control study from Malawi showed a twenty-seven percent (27%) improvement in survival of neonates with RDS after the introduction of NCPAP versus oxygen therapy [33]. This was consistent with a prospective pre-and post-intervention study using CPAP in Nicaragua that showed mortality

reduction by a half and intubation reduction by 33% [34]. A randomized control trial done in Tanzania showed a 52% lower risk of death with the BCPAP group [35]. A similar study in Kenya showed survival rates of 61% vs. 85% for pre-BCPAP and post low cost BCPAP group respectively [36]. On the other hand, a systematic review in 2020 showed clinical improvement and mechanical ventilation reduction without change in mortality by BCPAP use [37]. In contrast, the BCPAP failure rate in an Indian study was higher at 42% in the RDS group compared to other CPAP indications studied including meconium aspiration syndrome [38]. The similar remarkable results were seen from LMICs with improvised NCPAP use [18, 36, 39, 40, 41].

In our study, key informants believed that infrastructure challenges, CPAP consumables, and inappropriate sizes of nasal prongs especially for preterm neonates hinder CPAP use. These findings are similar to a systematic review from seventeen (17) studies done in SSA that showed unavailability of CPAP machines, and shortage of consumables were recurrently stated barriers to bubble CPAP implementation [18]. A related study done in Kenya found the same barriers to using CPAP to be infrastructure-related challenges, inadequate and inappropriate size of consumables mainly nasal prongs, and this happened mostly after completion of donor's implementation [19]. Another study in India showed that lack of sufficient equipment and consumables changed health care workers' perception of CPAP quality and effectiveness [31]. Therefore, these are challenges faced by limited settings like ours where NCPAP devices are donated without a sustainable plan for supply of consumables or maintenance by the manufacturers in conjunction with the Engineering department. Furthermore, there is need for training and capacity development of our biomedical engineers organized by the manufacturers on the common faults of these equipment and cost-effective maintenance. [42]. Timely maintenance of NCPAP machines and consumables was highlighted as a challenge by our key informants, this was in-line with a study in Ghana [43].

In addition, our findings showed that sometimes CPAP machines and consumables might be available, however, staff shortage might delay its initiation and monitoring. Health workers in Malawi recently expressed concerns they face especially when there is a shortage of cover which may lead to delayed CPAP initiation and poor monitoring [23]. Increased workload of health care workers by many patients in India was thought to lead to poor neonatal outcomes and mortalities without close monitoring [31]. This was in agreement with a study in Kenya [44]. A systematic review in SSA did show workloads in the units affects the quality of care and training opportunities [18]. Nevertheless, there is a need to think about world health organization recommendations on task shifting which would help in improving access to newborn health interventions in such staff shortage situations [45,46].

Our study participants believed that global evidence of CPAP efficacy enabled its use. This was commonly mentioned in different studies [47- 49]. On the other hand, the barriers to NCPAP use were alleviated by promising outcomes of CPAP in a recent Kenyan study [19]. Our findings also underlined that; staff training facilitated NCPAP use, this is in-line with findings from an observational study from a rural Ugandan neonatal Intensive Care Unit (ICU) [50]. In Malawi, the competency in using CPAP increased from thirty-two percent to ninety-seven percent, and CPAP use improved by sixteen percent after the peer mentorship program [38]. A similar study from AIC Kijabe Hospital Nursery, Kenya showed higher survival to discharge rates, the adequate training of staff after the introduction of CPAP which concurred with the hiring of a clinical officer likely enabled staff to initiate CPAP safely, and hence resulted in favorable outcomes [36]. A related study in Kenya on effective training of trainers after NCPAP implementation showed promising results on successful initiation of CPAP by nurses [42]. The health partnership and international experts' upkeep on training schemes have been shown to improve CPAP uptake in the newborn care units from four different hospitals in Rwanda [43]. On the other hand, insufficient training was mentioned as a barrier to NCPAP use, and hence frequent training/Continuous medical education (CMEs) and mentorship was thought to play an important role in CPAP use by our study participants. Two studies in Rwanda and Ghana presented a challenge in the identification of eligible neonates after short training [43, 51]. Carns et al, recently highlighted that training and mentorship do increase CPAP uptake [52]. The limitation of this study is that the enrollment of the preterm neonates in terms of gestational age was based on Ballard's score done by the admitting clinician especially for those preterm neonates with unknown GA or undocumented first trimester ultrasound scan. Secondly, it would have been better to look at missed opportunities for Bubble versus other forms of NCPAP machines to know which type of NCPAP machines are frequently in use for deeper understanding of the opportunities we have for improvement. Lastly, recall bias for key informants may have occurred given certain answers required recall; however, they were given ample time to answer questions. Nevertheless, this study ensured a fairly accurate representation of NCPAP users in Kenyatta National Hospital. We involved Key informants from different health care professionals and engineers that deal with NCPAP routinely in their work. This was to gain a deeper understanding of the facilitators and barriers to NCPAP use.

CONCLUSION

This study shows that progress has been made. There is a 23.4% reduction in NCPAP missed opportunities in the Newborn unit, KNH five years after an earlier study was done in 2016. However, we still have missed opportunity for NCPAP at 33.5% [95% CI 59.0% - 73.2%] in NBU, KNH. Missed opportunity for prophylactic group and SAS group was found to be 44.7 (34.1% - 55.9%) and 24.2 (16.5% - 33.9%) respectively.

Barriers to NCPAP use were related to medical products and technologies, health workforce challenges, and service delivery. Solutions highlighted by the key informants are: provision of more NCPAP machines, human resource support, frequent training/CMEs/mentorship,

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2
3 infrastructure improvement, adequate and appropriate size of consumables, promotion of family-
4 centered care, and engagement of the equipment’s manufacturer. Future CPAP scale-up should
5 provide more NCPAP machines including supporting infrastructure and appropriate consumables,
6 human resource support, frequent training and mentorship on NCPAP use. This study was done
7 when new NCPAP machines were being introduced in the unit and therefore, a similar study in
8 the future including caregivers and focus group discussions would help in quality care
9 improvement.

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35 **Contributors**

36
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53
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Patient consent for publication

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Ethics approval

The project was approved by the Kenyatta National Hospital/ university of Nairobi ethics research committee (P206/03/2021). Written informed consent was sought from both qualitative and quantitative study participants.

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Figure 1. Major themes on Benefits, Facilitators, Barriers of NCPAP use and Solutions

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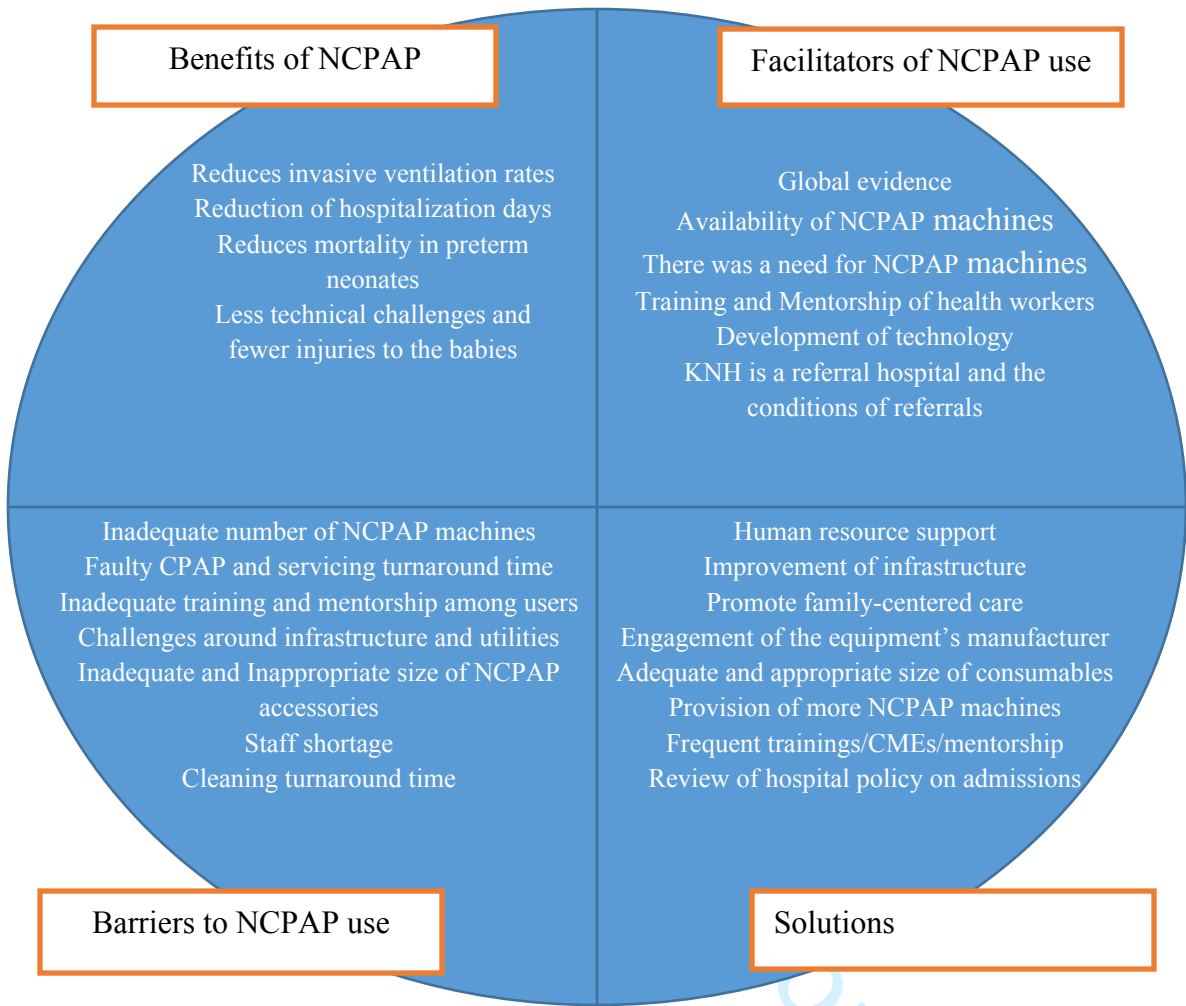


Figure 1. Major themes on Benefits, Facilitators, Barriers of NCPAP use and Solutions

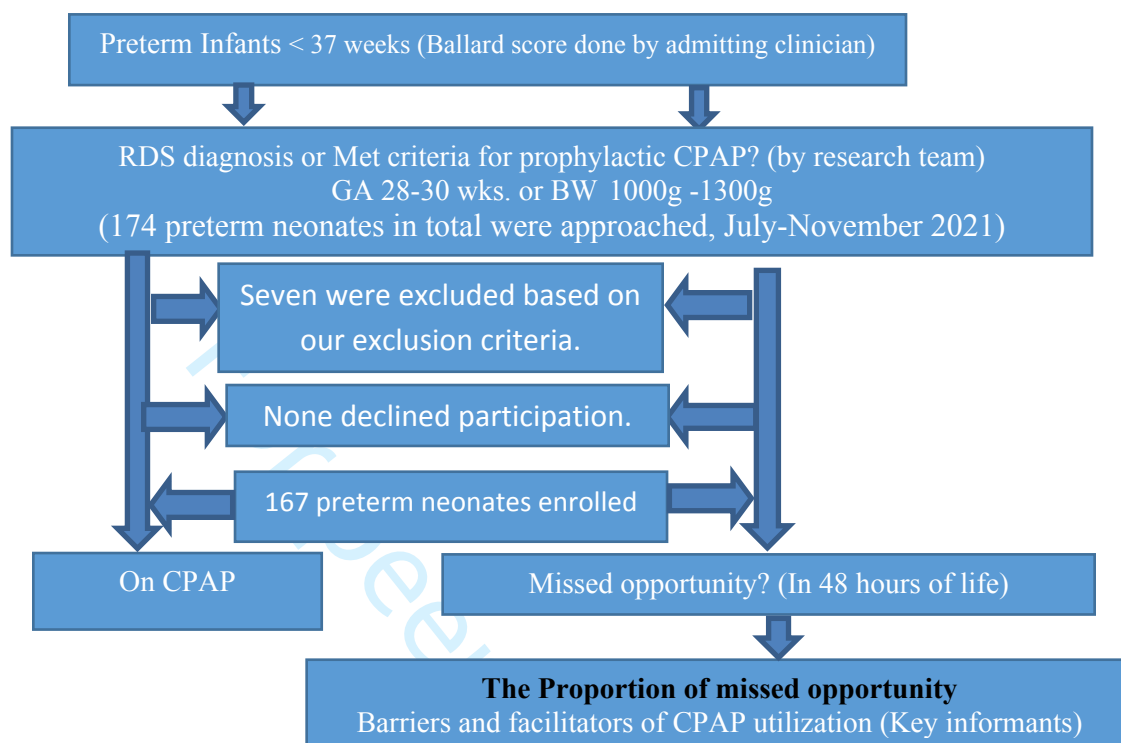


Figure S1. Study summary for quantitative study

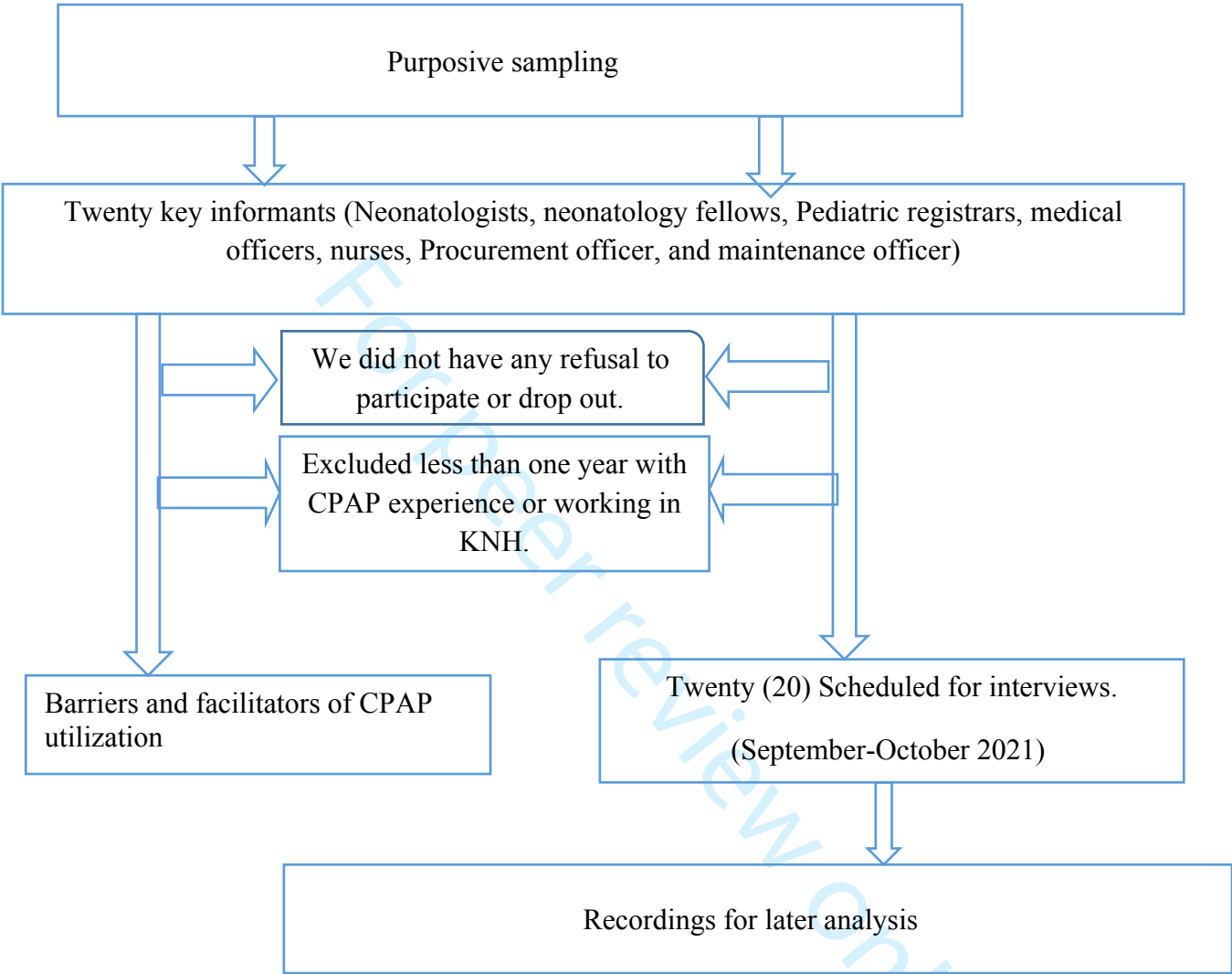


Figure S2. Study summary for qualitative study.

Table S1: SAS group (4-6) (exclusion of those in the prophylactic group).

		Frequency (<i>n</i> =91)	Percent	95% CI
CPAP management	Yes	69	75.8	66.1% - 83.5%
	No	22	24.2	16.5% - 33.9%
Total		91	100	

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Missed opportunity for Nasal Continuous Positive Airway Pressure in preterm neonates admitted at tertiary level hospital, New Born Unit in Kenya- A mixed method study.

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**1Missed opportunity for nasal continuous positive airway pressure in preterm neonates
2admitted at a tertiary level hospital newborn unit in Kenya - a mixed method study**

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24 **ABSTRACT**

25 **Background:** Respiratory distress syndrome (RDS) is the commonest complication of preterm
26 neonates. It remains one of the major public health concerns that contribute to neonatal mortality
27 and morbidity, especially in Africa where 80% of neonatal mortality is estimated to be caused by
28 preterm complications. Nasal continuous positive pressure (NCPAP) ventilation is the preferred
29 mode of RDS treatment. However, NCPAP is not easily accessible to every preterm neonate in
30 low and middle-income countries (LMICs) and this is the case in Kenya.

31 **Objectives:** To determine the proportion of preterm neonates admitted to the newborn unit at
32 Kenyatta National Hospital (KNH), a tertiary referral hospital in Kenya, with a missed opportunity
33 for NCPAP, and to determine the barriers and facilitators of NCPAP utilization.

34 **Design and setting:** We conducted a hospital-based cross-sectional study that employed
35 interactive explanatory concurrent mixed methods. The quantitative approach determined the
36 proportion of missed opportunities for NCPAP in preterm neonates admitted in the KNH newborn
37 unit while the qualitative approach explored the barriers and facilitators of NCPAP utilization.

38 **Participants:** Preterm neonates of gestation less than 37 weeks in the first 48 hours of life who
39 met the criteria for NCPAP. The key informants were mainly, different staff cadres from the
40 newborn unit, a procurement officer, and a biomedical engineer.

41 **Primary and secondary outcome measures:** The proportion of preterm infants admitted to the
42 newborn unit with a missed opportunity for NCPAP, and the barriers and facilitators of NCPAP
43 utilization.

44 **Results:** One hundred and sixty-seven (167) preterm neonates were reviewed from July to
45 November 2021 and analyzed of whom 33.5% [95% CI 26.8% - 41.0%]. missed the opportunity
46 to receive NCPAP. Twenty key informants were interviewed from September to October 2021.
47 Facilitators of NCPAP use reported were: i) training of health workers, ii) availability of NCPAP
48 machines, iii) KNH being a national and tertiary referral hospital able to receive neonates referred
49 with RDS, iv) global evidence that NCPAP use is beneficial, and v) technology development.

Barriers to NCPAP use were mainly: i) inadequate number of NCPAP machines, ii) inadequate training and mentorship, iii) inadequate and inappropriate size of NCPAP consumables, iii) staff shortage, iv) long servicing turnaround time, v) long cleaning turnaround time, vi) infrastructure challenges and vii) insufficient utilities.

Conclusion: The missed opportunity for NCPAP in preterm neonates in Kenya is high. Barriers to NCPAP are related to medical products and technologies, health workforce related challenges, and service delivery. We recommend the provision of more NCPAP machines including supporting infrastructure and appropriate consumables, human resource support, frequent training and mentorship on NCPAP use.

Keywords: Africa, Barriers, Facilitators, Neonates, Non-invasive ventilation, Nasal continuous positive airway pressure (NCPAP)

Study strengths and limitations

- This study ensured a fairly accurate representation of NCPAP users in Kenyatta National Hospital, a public tertiary level health facility in Kenya. We involved NCPAP users from different cadres to gain deeper understanding of the facilitators and barriers to NCPAP use.
- The limitation of this study is that the gestational age was based on a Ballard's score determined by the admitting clinician. Our data reflects a real-world scenario in many low-and-middle-income countries, where for determination of gestation we relied on the Ballard Score because in our setting a lot of mothers are unsure of their last menstrual period dates and first trimester ultrasound scan results are largely unavailable.
- Recall bias may have occurred because certain responses by key informants required recollection, however, they were given ample time to answer questions.

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74 **BACKGROUND**

75 Prematurity is a global concern. Half (50%) of these neonates develop respiratory distress
76 syndrome (RDS) [1-4]. Respiratory distress syndrome occurs commonly with preterm neonates
77 and has been found to be associated with higher mortalities in many low-and-middle-income-
78 countries (LMICs) including African nations [3,5-7]. Nasal continuous positive airway pressure
79 (NCPAP) reduces RDS mortality and the need for mechanical ventilation by almost half [8]. In
80 low-and-middle-income-countries (LMICs), mechanical ventilation, surfactant, and NCPAP are
81 not easily accessible to every preterm neonate in need and this is the case in Kenya [8]. There
82 have been a lot of efforts in limited settings to scale up NCPAP use by using improvised and low-
83 cost bubble NCPAP machines to improve neonatal survival [9, 10].

84
85 Despite improvised NCPAP being a promising track in LMICs, there are still barriers to its
86 implementation [9, 11, 12]. A slow reduction in neonatal mortality has been observed worldwide
87 thus the World Health Organization strongly recommends the use of NCPAP in preterm infants
88 [13]. Focusing on effective interventions for RDS would decrease neonatal mortality in LMICs
89 [14]. Missed opportunity for NCPAP in developed countries would mean that infants met criteria
90 for CPAP, but other interventions like mechanical ventilation were instituted instead [15]. In
91 LMICs, the missed opportunity for NCPAP is common due to NCPAP unavailability or
92 infrastructure constraints among other barriers [12, 16].

93
94 In a public tertiary and referral hospital in Western Kenya, RDS was the most common reason for
95 admission of preterm neonates (57%), with 73% of the overall deaths caused by RDS [17]. A
96 study done in KNH by Nganga et al, in 2016 revealed that almost 60% of preterm infants were
97 eligible for NCPAP but did not get it. However, reasons behind this were not captured in this study
98 [18]. Missed opportunities in KNH remain unclear with gaps that limit the understanding of what

could be the reasons behind a missed opportunity for NCPAP. This study aimed to find out the proportion and factors associated with a missed opportunity for NCPAP in preterm infants admitted in the newborn unit, KNH.

METHODS

Study design

We conducted a hospital-based cross-sectional study and employed interactive explanatory concurrent mixed methods (qualitative and quantitative methods). The quantitative approach determined the proportion of missed opportunities for NCPAP in preterm neonates admitted in the newborn unit at KNH from July to November 2021 while the qualitative approach explored the barriers and facilitators of NCPAP utilization from September to October 2021. This mixed method approach helped us to understand the NCPAP missed opportunities in-depth and identify solutions to barriers of NCPAP use. The University of Nairobi - KNH Ethics Research Committee approved our study (P206/03/2021). We obtained written informed consent from each study participants.

Study Population and Setting

This study was carried out at Kenyatta National Hospital, a public, level six referral hospital in Kenya's capital Nairobi. It serves as the teaching hospital of the University of Nairobi and provides specialized tertiary health services for both adults and children in Kenya. On average, approximately 1200 neonates are admitted to the newborn unit annually from the labor ward, maternity theatre, post-delivery wards and referrals from other facilities.

We included eligible preterm neonates < 37 weeks gestational age with moderate respiratory distress as per the Silverman Anderson Score ranging from 4-6 [19], within 48 hours of life and those who met the inclusion criteria for prophylactic NCPAP according to the comprehensive

newborn care protocols as demonstrated in Figure 1 [19]. Admitting clinicians determined each neonates Ballard's score to clinically ascertain their gestational age. The RDS severity depended on clinical signs, The Silverman Anderson Score consists of 5 signs. It indicates the degree of respiratory severity and helps in identifying children who need respiratory support. Rescue NCPAP is indicated when the Silverman Anderson Score is 4-6 signifying moderate respiratory distress [19-21]. On the other hand, prophylactic CPAP is indicated when preterm neonates have a gestational age of 28-30 weeks or birth weight of 1000-1300g [18].

We conducted in-depth interviews with a representative sample of key informants who deal with NCPAP daily at KNH from the newborn unit, procurement, and biomedical engineering departments. We specifically included neonatologists, neonatal fellows, paediatric registrars, medical officers, bedside nurses, an equipment nurse, a procurement officer, and a biomedical engineer, see **Figure S1 and S2**.

Sampling

For the quantitative component of our study, the sample size was determined by using the Fisher's formula [22]. A prior study conducted in KNH revealed that 57% of neonates did not get CPAP despite being eligible [18]. With the level of precision set at 7.5%, the estimated sample size was 167 patients. In the same study, forty-seven infants met the criteria for prophylactic CPAP while fifty-five had Silverman Anderson Scores of 4-6. Using a stratified sampling technique, we aimed to balance the two subpopulations, 76 for the prophylactic CPAP group and 91 for those who developed RDS and had a Silverman Anderson Score of 4-6.

For the qualitative component of our study, participants were approached by the principal investigator and research assistant using purposive sampling, twenty (20) key informants were selected and projected to reach saturation based on a study by Morse et al, [23] whereby no new information emerged from additional participants.

Data collection

This study was conducted from July to November 2021. In the quantitative component of our study, the principal investigator and research assistant prospectively abstracted demographic and clinical data from patient files into case report forms. In the qualitative component of this study, the data were collected using open guided interviews by the principal investigator and research assistant who were all practicing health care workers and had used NCPAP machines in training and work. Both were females and had received training in conducting in-depth interviews. Furthermore, both investigators were fluent in both English and Swahili, the two national languages widely spoken in Kenya. The interview guide (**Figure 1**) used was pilot tested. Participants were approached by the principal investigator and research assistant using purposive sampling. Twenty key informants were selected to reach saturation, 18 of them had face-to-face interviews and two had zoom meetings which were recorded with informed consent obtained from study participants. No participant refused to participate or dropped-out. The interview sessions were audio recorded by a handheld tape recorder in addition to the field notes taken during interviews. No other person was present during the interview sessions. The sessions were conducted in English and took approximately 20 minutes for each participant. Key informants were informed that if they wished to express their views in Swahili, they would be given a chance to do so. However, they were all comfortable and expressed their views in English. The investigators noted when data was saturated, and did not return transcripts to the participants or repeat interviews.

171

172 Data Analysis

173 The data from the questionnaire were exported and cleaned in Excel, coded, and analyzed using
174 STATA. Descriptive analysis was performed to determine proportions in all variables. These were
175 summarized in frequency tables and charts. The proportion of missed opportunity was computed
176 by the number of infants who missed the chance to get NCPAP as the numerator, and the total
177 number of eligible preterm infants as the denominator. We converted the proportion to a
178 percentage and estimated a 95% confidence interval.

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180 For qualitative analysis, a hybrid approach to data analysis was employed. The deductive
181 approach was based on our conceptual framework developed from the literature review [13,17]
182 and an inductive approach, in which we were open to new themes that emerged during data
183 collection (**Figure 1**). Audio recordings from in-depth interviews were transcribed verbatim by the
184 independent transcriber (anthropologist and a population studies researcher) and the research
185 team. NVIVO software version 12 was utilized for data management [24]. This transcription
186 happened within one week after the recordings and analysis was conducted, guided by the
187 thematic approach. The data analysis was an iterative process initiated alongside data collection,
188 enabling the exploration of key emerging themes. After thoroughly familiarizing with the data,
189 anthropologist and population studies researcher together with the investigators developed a
190 coding scheme, which was further refined during the analysis to enhance the robustness of the
191 approach. The findings were aggregated, coded progressively, and line-by-line read to identify
192 central themes. The central themes were revised to identify sub-themes, reports abstracted to
193 findings, and these findings were presented in the form of direct quotations from the responses
194 of participants. Data was integrated by merging two data sets for analysis and a joint display was
195 used whereby the quantitative and qualitative data were listed in different sections with an
196 integrative statement.

Patient and public involvement statement

We did not involve the public or patients in the design or operationalization of this study.

RESULTS

Quantitative results

Data from 167 preterm neonates were analyzed. Seventy-six of them met the criteria for prophylactic NCPAP and 91 had a Silverman Anderson Score between four and six. Eighty-eight (52.7%) were male and most neonates 63(37.7%) were between 28-32 weeks gestational age as shown in **Table 1**.

Table 1: Characteristics of the Preterm infants with RDS.

		Frequency (n=167)	Percent	Mean (SD)
Sex	Male	88	52.7	
	Female	79	47.3	
Birth weight	Median (IQR)			1391.4 (468.4)
	1300.0 (1050.0 – 1700.0)			
	ELBW (≤ 1000)	33	19.8	850.9 (112.6)
	VLBW (1001 – 1500)	82	49.1	1233.0 (140.0)
	LBW (1501 – 2500)	51	30.5	1970.2 (280.5)
	>2500	1	0.6	2510 (-)

Gestation age	Median (IQR)			
	30.0 (28.0 – 34.0)			
Mode of delivery	<28 weeks	24	14.4	26.2 (0.7)
	28 to <32 weeks	63	37.7	29.1 (0.9)
	32 to <34 weeks	32	19.2	32.9 (0.3)
	34 to <37 weeks	48	28.7	34.8 (0.8)
Gestation	Single	146	87.4	
	Twin	17	10.2	
	Triplet	4	2.4	

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Table 2 shows all neonates enrolled. The proportion of missed opportunity for NCPAP was found to be 56/167 (33.5% [95% CI 26.8% - 41.0%]). Many of the neonates got NCPAP, 111/167 (66.5 % [95% CI 59.0% - 73.2%]). **Table 3 and (Table S1)** shows two subpopulations, the prophylactic NCPAP group and those who had Silverman Anderson Score 4-6 that we enrolled using a stratified sampling technique. Thirty-four (44.7%) [95% CI 34.1% - 55.9%] in the prophylactic group missed opportunity for NCPAP compared to twenty-two (24.2%) [95% 16.5% - 33.9%] in the group with a Silverman Anderson Score of 4-6.

Table 2: All preterm neonates enrolled

			Frequency (n=167)	Percent	95% CI
NCPAP management	Yes	111		66.5	59.0% - 73.2%
Missed NCPAP	No	56		33.5	26.8% - 41.0%
Total		167		100	

Table 3: Prophylactic CPAP group ((1000-1300g or 28-30 weeks)

			Frequency (n=76)	Percent	95% CI
NCPAP management	Yes	42		55.3	44.1% - 65.9%
	No	34		44.7	34.1% - 55.9%
Total		76		100	

Qualitative results

We conducted 20 key informant interviews among different cadres working in NBU, biomedical engineering, and procurement departments. The majority were females at 55% and nurses accounted for 45% of the study population. Average years of experience was four years in their respective departments and the average age was 38.9 years with the oldest being 56 years old and the youngest 27 years of age as shown in **Table 4**.

Table 4: Demographic characteristics of the key informant interviews.

Demographic characteristics	Number (n)	Percentage (%)
Neonatologists	2	10
Neonatology fellows	1	5
Paediatric registrars	3	15
Medical officers	2	10
Nurses	9	45
Maintenance engineer	1	5
Procurement officer	1	5
Equipment nurse	1	5
Women	11	55
	Median (IQR)	

Age in years	38.9 (29-40)	
Years of experience in the respective departments	4 (3-10)	
Years of experience with CPAP usage	3 (2-5)	

Benefits of CPAP

NCPAP use was reported to be beneficial, reduce mortality, especially in preterm neonates, and help move away from invasive ventilation. NCPAP was reported not to have technical challenges compared to invasive mechanical ventilation. **Figure 1.**

Reasons associated with missed opportunities for CPAP

Although participants highlighted that NCPAP is beneficial, there were challenges associated with its use. Several barriers were mentioned to NCPAP use namely: (1) the inadequate number of NCPAP machines; (2) inadequate and inappropriate size of NCPAP accessories especially for extremely preterm neonates; (3) inadequate training among users leading to a lack of confidence and competency to start NCPAP; (4) lack of mentorship on NCPAP usage; (5) lack of adequate infrastructure to facilitate its use as well as insufficient utilities like oxygen points; and (6) staff shortage especially for monitoring and cleaning NCPAP equipment after use. **Figure 1.**

Inadequate number of NCPAP machines

This was highlighted as the major barrier to NCPAP use. The inadequate number of NCPAP machines was because the unit is a referral hospital and thus receives many preterm neonates in need of NCPAP machines. Therefore, the numbers in need outweighed the available machines. When the babies were many and the NCPAP machines are few, the Silverman Anderson Score,

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age, and condition of the baby were used to determine which baby to start on NCPAP using clinical judgment, and thus NCPAP was given to the baby who was felt to benefit the most.

“I have encountered that experience several times, it is an everyday encounter, no CPAP. Actually, when you plan as a doctor for CPAP, you just write for CPAP when available because it is not available at that given time, yeah.” **Paediatric Registrar, DF01**

Faulty CPAP and servicing turnaround time.

It was noted throughout the interviews that some NCPAP machines would be faulty and need out sourced servicing. In some instances, their repair would be prolonged or delayed and even those that were repaired locally by KNH engineers would require external spare parts that needed to be requested through the procurement/supplier chain. This process would take long and some machines would not be in use for some time.

“There are machines that require outsourced services, we ask for this service and the procurement process; the servicing might take long..., there are those machines that we service ourselves, but we still require parts, the same thing will happen. It is not necessarily a problem with the procurement but it can also be the supplier; you tell them bring this then the supplier tells you that there is no what....” **Biomedical engineer, M01.**

“All the machines are on service contract ..., the challenge might be follow-up and probably even the supplier may take the advantage come and say am fixing this... maybe there is that...”. **Procurement officer, M01.**

Cleaning turnaround time.

It was noted that even when machines were available, they needed cleaning and disinfecting after use. It was noted during interviews that there was only one nurse in charge of equipment and part of his/her responsibilities was to clean and disinfect machines after use so that they could be

275 available for the next use. However, over the weekend and during the nights, the nurse in a
276 particular room who needed to put the baby on NCPAP machine, had to spare time to disinfect
277 the equipment before use. This would take some time due to a shortage of staff and in turn, would
278 delay the start of NCPAP.

279 "There is one person who does cleanings of equipment's and it's not only CPAP only. So, waiting
280 time may be prolonged." **Nurse, F01.** "It depends, if they have all been occupied then that
281 becomes a problem, on the weekends, some CPAPs have not been cleaned or there is usually
282 no one to clean them. So, the nurse who is in a certain room, if you need CPAP, you need to
283 clean CPAP, you see and it is very tedious because they are also doing other things." **Medical**
284 **officer, F01**

285 *Inappropriate size of NCPAP accessories.*

286 It was noted that consumables, mostly nasal prongs contributed to the missed opportunity for
287 NCPAP. This is because KNH receives extremely preterm neonates that may not be able to use
288 the same size of nasal prongs as late preterm or term neonates.

289 " Sometimes we get extreme preterm neonates; so, you find that even the smallest size of prongs
290 doesn't fit so you find that it is difficult delivering the pressure and oxygen, due to the fact that
291 prongs keep moving out..." **Nurse, F05**

292 *Inadequate NCPAP accessories*

293 Consumables were also highlighted as not adequate. Moreover, some would get lost or punctured
294 and no longer deliver the pressure or oxygen needed. The supply of consumables was said to be
295 inconsistent since this was based on the budget allocated to the general paediatric department.

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296 “For intensive care unit set up, it should be independent to be able to have its own budget, its
297 own procurement... So, all these are based on the general pediatrics department, we have always
298 run out of supplies.” **Neonatologist, DM03**

299 *Inadequate training and mentorship among users.*

300 Lack of training and mentorship among the users led to a lack of confidence and competency to
301 start NCPAP among the health care workers. It was noted that knowing how the machine works
302 was very crucial in starting NCPAP timely and monitoring a patient on NCPAP, especially with
303 new machines. However, it was highlighted that most staff were trained on how to use NCPAP
304 which made a difference with regards to competency and confidence in using and starting NCPAP
305 compared to previous years where some of the health care workers had to learn from their co-
306 workers. Despite the training that helped in this regard, not all staff had the chance to be trained
307 due to staff shortages.

308 “The other one is competency, if someone is not competent and confident about using it, they
309 pass it over to the next shift person. So, you will write in the file, start CPAP but they will keep
310 moving around hoping their shift can end and someone else can come and put it.” **Neonatology
311 fellow, DF01**

312 *Challenges around infrastructure and utilities*

313 Lack of appropriate infrastructure to facilitate NCPAP usage was highlighted by key informants,
314 especially due to limited space. Some NCPAP machines, specifically Vayu bubble NCPAP,
315 needed to be placed on resuscitaires which sometimes would not be available... Sometimes
316 babies shared a single incubator which made it difficult to start NCPAP due to constraints of space
317 and oxygen outlet ports. It was noted that Pumani NCPAP machines needed a lot of space which
318 would be a challenge in a room that had many admissions or patients.

319 "The other thing is even a bed, you may be told the baby is in incubator and putting CPAP in an
320 incubator where babies are sharing an incubator is a challenge." **Nurse, M03** "the most
321 concerning challenge actually is the ports; the oxygen outlet ports because they are not enough."

322 **Nurse, F04**

323 *Staff shortage*

324 Challenges around human resources were highlighted. It was mentioned that the unit had one
325 equipment nurse who did not work weekends and nights. In case a NCPAP machine was needed
326 when the equipment nurse was not available, the nurse in the unit with the neonate needing
327 NCPAP had to clean it herself/himself. Additionally, resuscitations or emergency procedures
328 would delay NCPAP initiation or become a missed opportunity. Furthermore, the study
329 participants highlighted that the new bubble NCPAP machines units (Vayu and Pumani), required
330 extra nursing care by frequent checking of nasal prong position and water levels. These additional
331 tasks with staff shortage were a challenge hence some patients were not getting the right pressure
332 or oxygen required.

333 "In this unit we have staff shortage, so most of the time it is one or two people in the room and as
334 we said CPAP is a form of respiratory support, you want to make sure your prongs are in, checking
335 water levels are okay. So, we have instances where, you actually walk in the room and the nasal
336 prongs are in the air... You can find one person nursing fifteen babies; will they have enough time
337 to check out on everybody..." **Neonatology fellow, DF01**

338 *The partnership between health care workers and caregivers on CPAP usage.*

339 Many of the participants cited that there was a need to improve the partnership between health
340 care workers and caregivers. The key informants noted that caregivers were not involved in the
341 process of initiating NCPAP. Some caregivers would find their babies on NCPAP and when the

nasal prongs were out of the nostrils, they wouldn't know how to put them back or that they needed to inform the nurses.

"There is a discrepancy because we tend to be overwhelmed with the number of patients, we have ... and the caretakers who are also supposed ... to understand how a CPAP works because for example, seven babies on CPAP but there are also other babies who are not on CPAP, they may be even more critical than those ones ... so you have to work between informing the mothers about the CPAP and resuscitation..." **Nurse, F03**

Facilitators of NCPAP use.

The fact that KNH is a referral facility that receives babies from peripheral facilities and varied conditions of babies led to NCPAP availability and provision in line with global evidence of CPAP efficacy. NCPAP training was highlighted as a factor that facilitated its use and competency among the users. **Figure 1.**

Training of health workers

Training that equipped health workers with the knowledge of NCPAP use was highlighted as an important factor that facilitated NCPAP utilization by increasing competency and confidence in the successful initiation, monitoring, and weaning off NCPAP machines.

"... we now have an induction program which includes respiratory support that includes CPAP, mechanical ventilation for new doctors rotating in the unit have to undertake..." **Nurse, M03**

Mentorship among the health care providers.

Mentorship which promoted NCPAP use especially when new machines were being introduced in the unit was highlighted to prevent delay in NCPAP initiation and prevent a negative approach toward new NCPAP machines in the unit.

“So, that acceptance of change is also an issue, so that is why we put the mentorship program so that people don’t have negative attitude towards a certain machine before they even try it... These new ones they keep slipping off more frequently especially the Pumani, securing the nasal prongs is still a problem. The bubble CPAP you have to keep checking water and adding which the other CPAP machine doesn’t have. These addition roles of these machines make some people shy away from them.” **Neonatology fellow, DF01**

Global evidence

The staff thought that global evidence in terms of NCPAP efficacy and reduction in mortalities facilitated its use in KNH newborn unit.

“Okay, there is global evidence to less push for ventilating babies, CPAP has been shown to be beneficial and with that kind of data worldwide and also within Africa, the move is now towards CPAP and advocate for that.” **Neonatologist, DM03**

Kenyatta National Hospital is a referral hospital

Kenyatta National Hospital is a national referral hospital that receives babies from peripheral health facilities as well as KNH labor ward and theater. The KNH labor ward receives high-risk deliveries including premature deliveries among other obstetric emergencies. Many admissions were noted to need advanced care or respiratory support, and this facilitated NCPAP use in the unit due to the condition of admissions on a daily basis.

“We admit babies from all over the country...so they all refer babies here and that is what led to us having the CPAP machines here because it is now basically the population of babies born in the whole country.” **Nurse, M01**

The participants were asked what type of support they would ask for if the Ministry of Health (MOH) or a sponsor wanted to offer the unit CPAP support? This was asked to try and understand

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the solutions to the mentioned challenges on NCPAP use. The themes that arose on solutions to barriers on NCPAP use are summarised in **Figure 1**.

DISCUSSION

Our study revealed the proportion of the missed opportunity for NCPAP of preterm neonates admitted to the KNH teaching and referral hospital NBU and explored the barriers and facilitators of NCPAP use from key informants.

The proportion of missed opportunities for NCPAP was considerably high, almost 35%, and which was higher when compared to a prospective study done in Malawi [22]. A Nigerian health facilities survey on accessible respiratory support showed oxygen to be the commonest available respiratory support at almost thirty-eight percent (38%) and 28% of the fifty-four facilities surveyed did not have any form of NCPAP machines [10]. This shows that we still have significant missed opportunities for NCPAP on the African continent. Nganga et al in 2016 found that almost 60% of preterm neonates that were admitted in the same NBU as our study did not receive NCPAP, despite being eligible [18]. Our study showed a 23% reduction in NCPAP missed opportunities in the NBU at KNH five years later. The contribution to this reduction could be explained by several factors including an increase in the number of NCPAP machines and staff training. An improvement was also seen at a county referral hospital 160 kilometers north of KNH that scaled up NCPAP use from 2% in 2016-2017 to 17% in 2018 after the quality upgrading initiative [25].

Despite the fact that NCPAP is beneficial as highlighted by our study participants and several other studies from LMICs [25-35], our key informants believed that infrastructure challenges, inadequate number of NCPAP consumables, and inappropriate sizes of nasal prongs especially for preterm neonates hindered NCPAP use. These findings are similar to a systematic review from seventeen (17) studies done in sub-Saharan Africa that showed that unavailability of NCPAP machines, and shortage of consumables were recurrently stated barriers to bubble

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3 412 NCPAP implementation [11]. A related study done in Kenya found the same barriers to using
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5 413 NCPAP to be infrastructure-related challenges, inadequate and inappropriate size of
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7 414 consumables mainly nasal prongs. This happened mostly after completion of donor
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9 415 implementation [12, 36]. Another study in India showed that lack of sufficient equipment and
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11 416 consumables changed health care workers' perception of NCPAP quality and effectiveness [26].
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13 417 These are challenges faced by limited-resource settings like ours where NCPAP devices are
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15 418 donated without a sustainable plan for supply of consumables or maintenance by the
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17 419 manufacturers in conjunction with the engineering departments [36]. Furthermore, there is need
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19 420 for training and capacity development of our biomedical engineers organized by the
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21 421 manufacturers on the common faults of these equipment and cost-effective maintenance [11,49].
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23 422 Timely maintenance of NCPAP machines and consumables was highlighted as a challenge by
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25 423 our key informants, in line with a systematic review in Sub Saharan Africa, 2020 [11].
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30 425 In addition, our findings showed that while sometimes NCPAP machines and consumables were
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32 426 available, staff shortage delayed its initiation and monitoring. Health care workers in Malawi
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34 427 expressed the concerns that they face especially when there is a shortage of cover which may
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36 428 lead to delayed CPAP initiation and poor monitoring [16]. Increased workload of health care
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38 429 workers by many patients in India was thought to lead to poor neonatal outcomes and mortalities
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40 430 without close monitoring [26]. This was congruent to a study in Kenya that employed an
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42 431 observational study on two hundred and sixteen neonates admitted to 6 healthcare hospitals in
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44 432 Kenya [38]. A systematic review depicting the sub-Saharan context showed that heavy staff
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46 433 workload in newborn units affects the quality of care and training opportunities [11]. Nevertheless,
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48 434 there is a need to consider World Health Organization recommendations on task shifting which
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50 435 would help in improving access to newborn health interventions in situations where there is staff
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52 436 shortage [39,40].
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Our study participants believed that global evidence of NCPAP efficacy enabled its use. This was commonly mentioned in different studies [41-43]. On the other hand, the barriers to NCPAP use were alleviated by the promising outcomes of NCPAP in a recent Kenyan study [12]. Our findings also underlined that staff training facilitated NCPAP use, which was in agreement with findings from an observational study from a rural Ugandan neonatal intensive care unit [44]. In Malawi, the competency in using NCPAP increased from 32% percent to 97% percent, and CPAP use improved by 16% after a peer mentorship program [45]. A similar study from the African Inland Church Kijabe Hospital newborn unit, a mission hospital situated approximately 60 kilometers from KNH, showed higher survival to discharge rates with adequate training of staff after the introduction of NCPAP into the NBU. This coincided with the hiring of a clinical officer who may have enabled staff to initiate CPAP safely resulting in favorable outcomes [31]. A related study in Kenya on effective training of trainers after NCPAP implementation showed promising results on successful initiation of NCPAP by nurses [46]. The health partnership and international experts' upkeep on training schemes have been shown to improve CPAP uptake in the newborn care units from four different hospitals in Rwanda [47]. In contrast, insufficient training was mentioned as a barrier to NCPAP use, and hence frequent training or continuous medical education and mentorship was thought to play an important role in NCPAP use by our study participants. Two studies in Rwanda presented short training challenges considering high staff turnover [47, 48]. Carns et al, recently in 2019 highlighted that training and mentorship do increase CPAP uptake [49].

Our study is not without limitations. Firstly, enrollment of preterm neonates in terms of gestational age was based on New Ballard's score done by the admitting clinician. The most accurate ways of determining gestation are a first trimester ultrasound and the last menstrual period. Secondly, it would have been better to look at missed opportunities for bubble versus other forms of NCPAP machines to know which type of NCPAP machines are frequently in use for deeper understanding

of the opportunities we have for improvement. Lastly, recall bias for key informants may have occurred given that certain answers required recollection. However, participants were given ample time to answer questions. Nevertheless, this study ensured a fairly accurate representation of NCPAP users in Kenyatta National Hospital. We involved key informants from different health care professionals and engineers that deal with NCPAP routinely in their work. This was to gain a contemporary and deeper understanding of the facilitators and barriers to NCPAP use.

CONCLUSION

This study showed that progress had been made. There was an over 20% reduction in NCPAP missed opportunities in the NBU at KNH five years after an earlier study that was done in 2016. However, we still have a significant proportion of neonates that missed the opportunity for NCPAP, with a higher proportion (almost double) among those that require prophylactic NCPAP compared to those with a moderate Silverman Anderson Score. Barriers to NCPAP use were related to medical products and technologies, health workforce challenges, and service delivery. Solutions highlighted by the key informants included provision of more NCPAP machines, human resource support, frequent training/CMEs/mentorship, infrastructure improvement, adequate and appropriate size of consumables, promotion of family-centered care, and engagement of the equipment's manufacturer. Future NCPAP scale-up should provide more NCPAP machines including supporting infrastructure and appropriate consumables, human resource support, frequent training and mentorship on NCPAP use. This study was done when new NCPAP machines were being introduced in the unit and therefore, a similar study in the future including individual interviews with caregivers and focus group discussions with newborn unit staff members may help in quality care improvement.

Acknowledgements

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No Conflict of interest to declare.

Contributors

PK coordinated the study, analyzed the data, prepared the manuscript and approved the final manuscript as submitted; Peace Kakibibi/PK acted as guarantor. She was the Principal Investigator of the study prior to the commencement of data collection and coordinated all aspects of the project. **FM and DM-B** analyzed the data, prepared the manuscript and approved the final manuscript as submitted.

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Patient and public involvement

No involvement of the public or patients in the design or conduction of this study

Patient consent for publication

Not applicable

510 Ethics approval

511 The project was approved by the Kenyatta National Hospital/ University of Nairobi Ethics
512 Research Committee (P206/03/2021). Written informed consent was obtained for both qualitative
513 and quantitative study participants.

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515 **Data availability statement:** All relevant data are included in this article. Additional data are
516 accessible by emailing kapeace12@gmail.com

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651 **Figure 1. Major themes on Benefits, Facilitators, Barriers of NCPAP use and Solutions**

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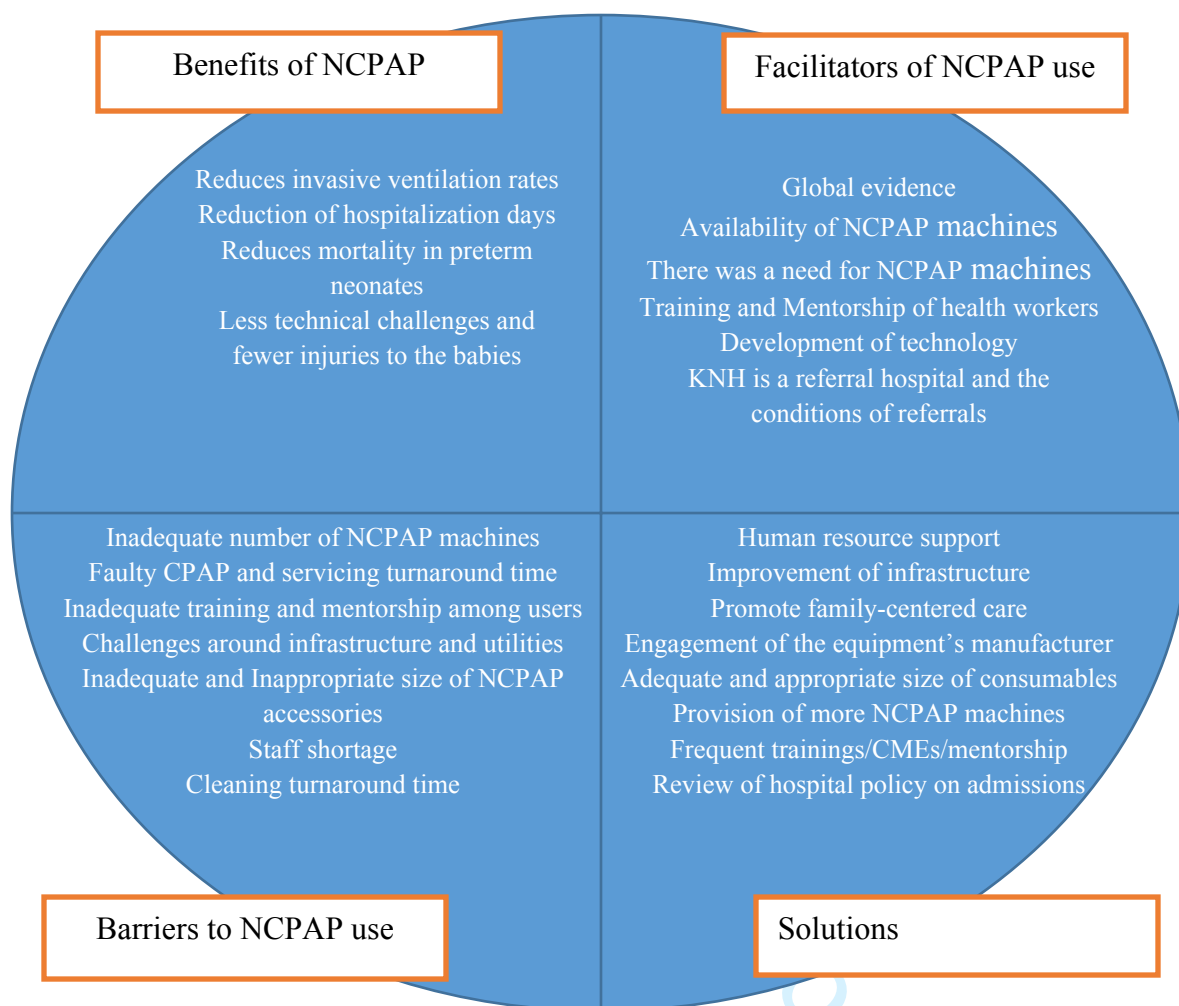


Figure 1. Major themes on Benefits, Facilitators, Barriers of NCPAP use and Solutions

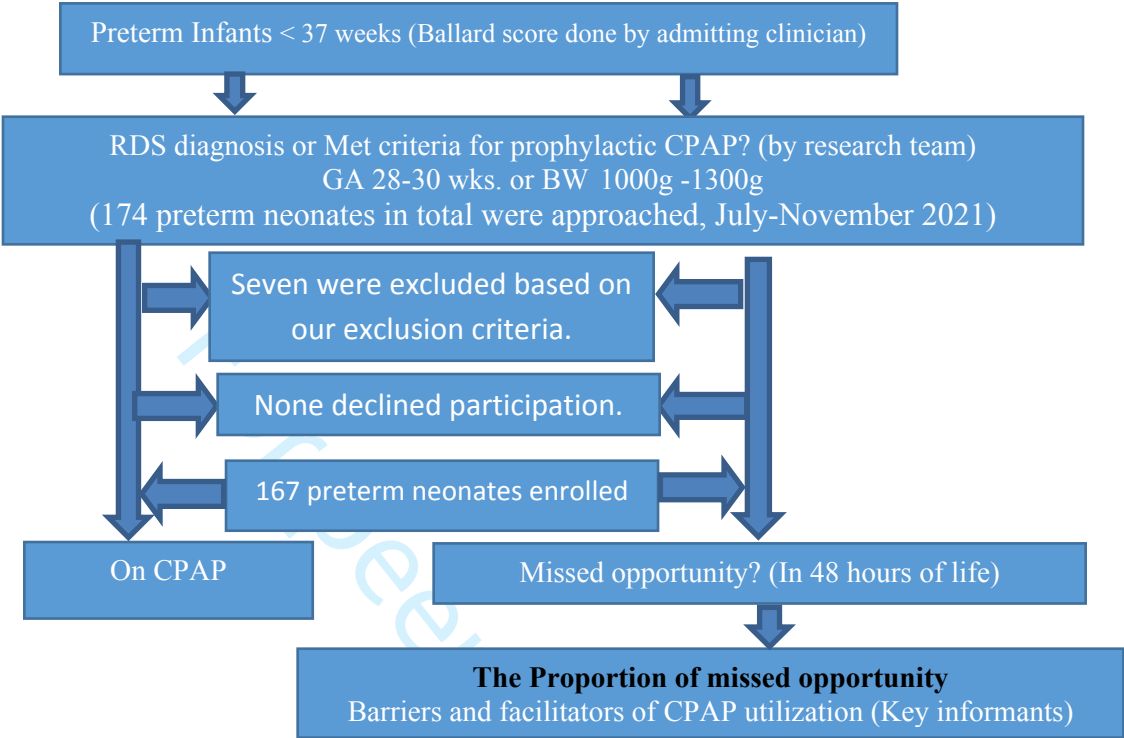


Figure S1. Study summary for quantitative study

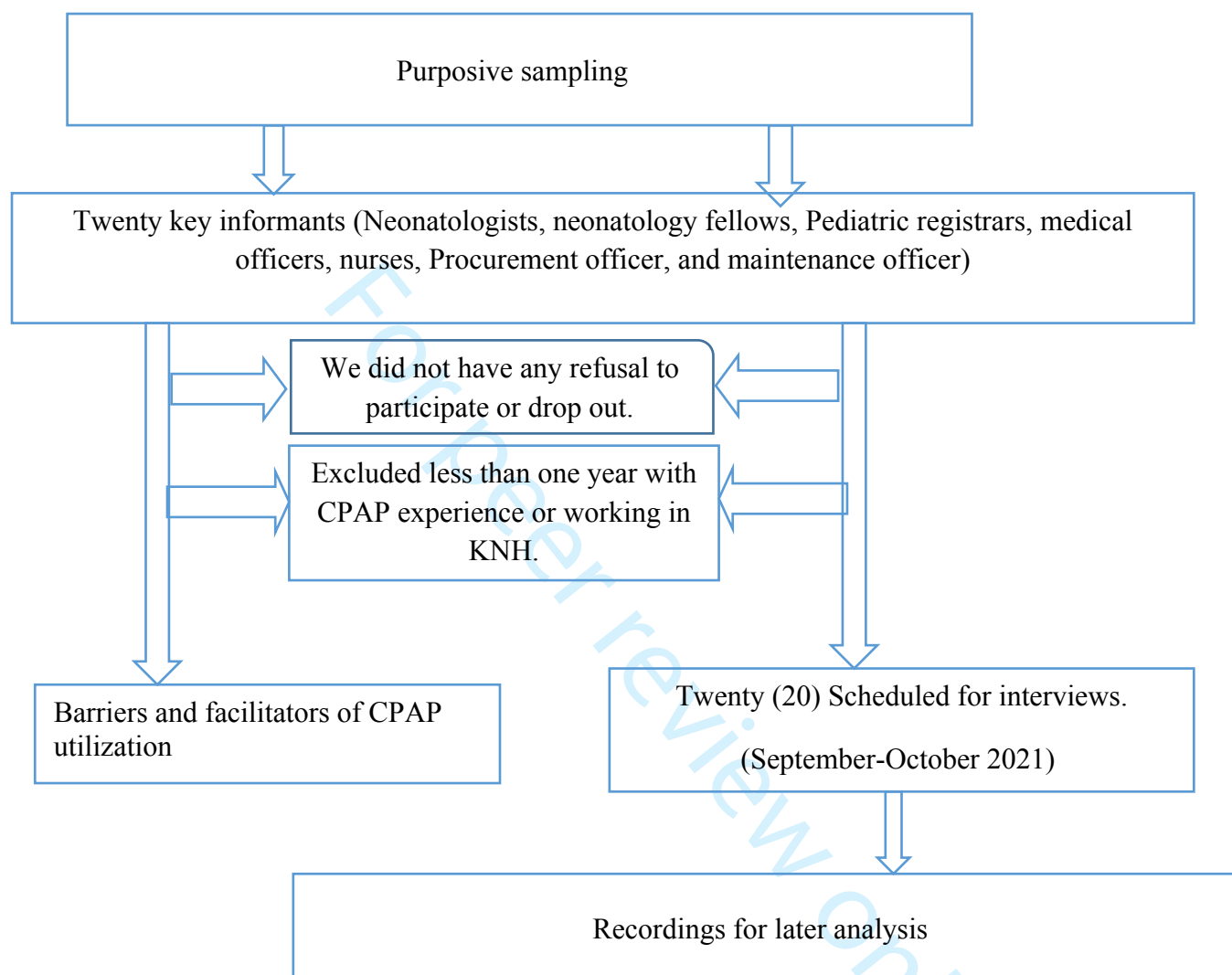


Figure S2. Study summary for qualitative study.

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Table S1: SAS group (4-6) (exclusion of those in the prophylactic group).

		Frequency (<i>n</i> =91)	Percent	95% CI
CPAP management	Yes	69	75.8	66.1% - 83.5%
	No	22	24.2	16.5% - 33.9%
Total		91	100	

For peer review only