Resource Allocation Models for Allocating Scarce Resources: A Rapid Review to Inform Referral in Pediatric Healthcare System

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ABSTRACT

Referral system plays a vital role in management of diseases in any healthcare system. However, unfavorable distribution of healthcare resources continues to hamper delivery of services particularly to pediatric patients, with estimated global mortality of 5 million every year. Whereas models for resource allocation for situating scarce resources are sufficiently documented, models for allocating resources for improving healthcare systems for pediatric patients are limited.

The authors conducted a rapid review of different models for allocating scarce resources during various situations such as emergencies, epidemics and pandemics. The researchers searched Medline, EMBASE, BMC, Open Access Journals and SCOPUS from April 2005 to April 2021. They also conducted full-text screening and data abstraction independently and in duplicate. Articles were included if they were primary research, focused on models for resource allocation for a particular situation, and the model described was related to a referral system. The paper summarizes each model including their elements and operating characteristics.

From 1,542 unique citations, 295 full-text articles were reviewed and 12 articles were included for analysis. Seven studies described critical emergency situations or pandemics and five described ethical models for various ailments. Of these, four studies described both protocols and ethical model for resource allocation during Covid 19. Six articles described unique triage or model criteria (two algorithm-based, three point-based) for resource allocation. Three described referral criteria, while three point-based models were good predictors of referral for improving healthcare system for pediatric patients.

This review summarizes available resource allocation models to provide decision-makers with data to help select and tailor allocation of healthcare resources, considered scarce. Given the uncertainty shrouding pediatric diseases and resource availability in healthcare systems especially in the developing countries, jurisdictions should prepare by selecting and adapting a model that works best for their circumstances.

Keywords
Resource allocation models; Healthcare resources; Covid 19; pediatric patients; Healthcare systems; Patient referral

1. INTRODUCTION
To allocate scarce resources among distributed healthcare users is a challenge for all health systems management globally (1 - 4). Decisions regarding allocation of healthcare resources without a model based on some responsibly structured model may result in marked patient-to-patient variability (5 - 6). Healthcare systems, denoted by sparsely located facilities, are loosely connected with undefined interdependencies in their software models, hence limiting the scope of optimization of distributed resources (7). In turn, nurse scheduling, patient appointment, medical resource planning and reallocation, emergency medical services, disease screening policy and hospital collaboration have remained poor (8). Resource allocation models so far documented have aimed at solving problems associated with allocating scarce resources during pandemics and emergencies, overlooking referral processes particularly for pediatric patients.

Resource allocation refers to the allocation of resources to a service, department or project (9 - 10). Resource allocation models in healthcare discussion have been adequately documented. Knebel et al (11) offered an ethical model and logic model for decision making during catastrophic disasters. The authors adapted medical triage and the federalism principle to the decision-making process for allocating scarce federal public health and medical resources. Timbie et al (12) developed and validated an algorithm to guide selection of patients for pediatric critical care admission during a severe pandemic when Crisis Standards of Care are implemented. Scott et al (9) explored allocative efficiency tools for guiding budget allocation decision in malaria funding in Nigeria. Lin, Taylor, and Cohen (13) developed a disaster triage tool for the evacuation of hospitalized neonatal and pediatric populations. They assessed inpatients using bedside visual assessments and chart review to categorize patients transport level based on local emergency medical services protocols and expert opinion. Naidoo and Naidoo (14) proposed a model for regional triage committees adapted to the South African context. The model consisted of the formation of Provincial multi-disciplinary Critical Care Triage Committees to alleviate the emotional, moral and legal burden on individual ICU teams and co-ordinate inter-facility collaboration using an adapted model. The foregoing studies suggest that resource allocation models for allocating scarce resources especially for improving pediatric patients' healthcare are scanty.

According to Yore et al (15), pediatric patients account for 20–35% of all emergency hospital visits globally. Moreover, children present a unique distribution of chief health complications compared to adults and require diverse clinical management (16). Housseine et al (17) posit that with over 5 million deaths every year, perinatal death remains a significant global health problem. The World Health

Organization (18) on their part reports that countries with the highest absolute numbers of stillbirths and neonatal deaths are in Asia and sub-Saharan Africa. Despite of tremendous reduction in mortality rate of children under 5 years, the Europe PMC Funders Group (19) report that 5.8 million children in this cohort died in 2015 globally. Neonatal deaths is estimated to account for 53.1% of the total under-5 deaths each year (20). Provision of healthcare to pediatric patients therefore seems to be a major challenge particularly in the Sub Saharan Africa including Kenya. This in turn demands for the understanding of effectiveness of models associated with resource allocation for pediatric patient referral improvement. One of the approaches adopted for improving access to quality healthcare is referral (21). A referral is a process in which a health worker at a one level of the health system, having insufficient resources (drugs, equipment, skills) to manage a clinical condition, seeks the help of a better or differently resourced facility at the same or higher level (22). According to Francetic, Tediosi and Kuwawenaruwa (23), the role of referrals in obstetric and childcare is crucial for the effectiveness of antenatal care but also for pediatric patients. Researchers (23 - 29) have reported that a high risk of child and maternal mortality is directly associated with inefficiencies in the referral system. However, challenges such as infrastructure, health information systems, capacity of health care workers, and financial resources often bedevil implementation of health care referral system in the developing countries such as Kenya (26 – 29). Therefore, efforts aimed at strengthening referral system endeavor to manage pediatric patients' health needs comprehensively by using resources beyond those available where they access care are imperative. To this end, in this review, we sought to identify, classify and assess the types of resource allocation models focused on improving referral for pediatric patients' health system.

2. METHODS

The study conducted a rapid literature review covering resource allocation models for allocating health resources, and referral systems for pediatric patients. This was done in line with the widely accepted Preferred Reporting Items for Systematic Review and Meta-analysis statement (PRISMA), as prescribed by Moher et al (30 - 32). Further, the guidelines proposed by Khan et al (34) i.e. (1) Framing the question; (2) Identifying relevant publications; (3) Assessing study quality; (4) Summarising the evidence; and (5) Interpreting the findings were adopted. The researchers begun by doing a simple search in Google Scholar using terms such as resource allocation models, resource allocation models for allocating healthcare resources, models for allocating resources in referral healthcare systems, and resource allocation models in referral systems for pediatric patients. Further, the researchers searched Medline, EMBASE, BMC, Open Access Journals and SCOPUS. Eligibility criteria was based on studies geared towards answering the question as to how resource allocation models aid in allocating scarce resources in healthcare referral system for pediatric patients (31). In addition, articles were included if they were primary research, focused on models for resource allocation for a particular situation, and the model described was related to a distributed or referral system. To ensure data quality, the researchers conducted full-text screening and data abstraction independently and in duplicate (32). The acronym PICOT informed the eligibility criteria for inclusion in the systematic review: the population (participants) of focus, types of interventions (and comparisons), and the outcomes of interest. The time relates to the period within which the studies were published (Table

1). The paper summarizes each model including their elements and operating characteristics.

Table 1: PICOT Based inclusion criteria

Patient Population	Pediatric patients (children under 5 years)
Intervention of interest	Allocation of resources guided by resource allocation model
Comparison interventions	None
Outcomes:	
Primary Outcome	Successful referral of pediatric patients
Secondary Outcome	Quality healthcare services and treatment, and good health
Time	2005 – 2021
Other considerations (Language)	English

The quality of the included articles was rated as either "poor", "fair" or "good" by three independent researchers (EO, MA and ZO), and EO made the final adjudication in cases of non-agreement. The rating of the articles was based on the criteria provided by Moher et al [30].

2.1 Data extraction

The data were extracted using an excel spreadsheet under the following headings: study setting, sample characteristics, intervention objectives, study design and methods, outcome measures and results.

2.2 Data analysis

We employed a thematic content analysis approach to distil information from the selected articles (34). The extracted information was coded into two broad categories: Intervention components and outcomes measured as informed by the study aim. The intervention components were classified along as: (1) How the interventions were administered; (2) who delivered the intervention; (3) Point of intervention delivery; and (4) components of the intervention. The outcomes were coded according to the reported primary and secondary outcomes of the study.

3. RESULTS

The literature search identified 2,591 unique citations (Fig. 1). After assessing titles and abstracts for eligibility, 1, 542 articles were included for full-text review. After screening for potentially relevant titles and abstracts 1, 247 articles were excluded. After screening full-texts, 283 papers were further excluded because they did not report on resource allocation models for allocating scarce healthcare resources during emergencies of for enhancing referral for pediatric patients. Subsequently, 12 papers were included in the review for final analysis.
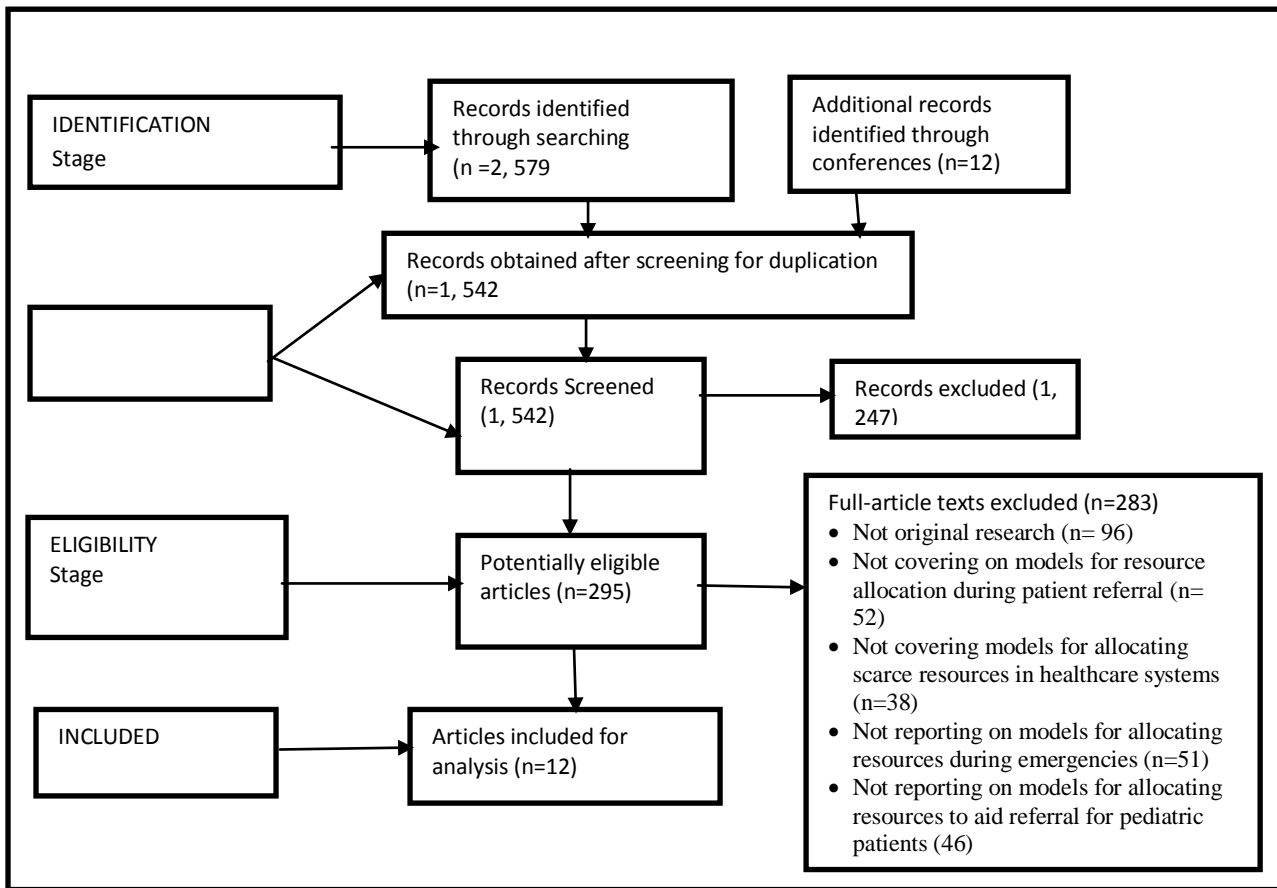
Figure 1: The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow protocol of study selection

3.1 Characteristics of included studies

The characteristics of the studies included in the review are summarized in Table 2. The 12 papers studies were conducted between 2012 and 2021. Four of the studies were conducted in United States of America (11. 12, 35, 36), two were conducted in South Africa (14, 37), while one study was done each in Italy, Taiwan, UK, Kenya, and Malawi (1, 8, 13, 29, 38). Six of the papers were retrospective cohort studies (12, 15, 35, 37, 39, 40), four randomized control trials (RCT) (1, 11, 13, 14), two mixed method involving qualitative and quantitative approaches (29, 38) and one system simulation study (8).

Table 2: Characteristics of included studies (n=12)

Characteristics	Counts	References
Year of publication		
2005 2011	0	
2011 – 2021	12	1, 2, 8, 11, 12, 13, 14, 15, 29, 35, 36, 37, 38
Country		
USA	5	2, 11. 12, 35, 36
Iran	1	8
Cambodia	1	15
Italy	1	1
South Africa	2	14, 37
UK	3	13, 39, 40
Saudi Arabia	1	38
Kenya	1	29
Study Design		
Retrospective cohort	5	12, 15, 35, 37, 39, 40
Randomised trial	4	1, 11, 13, 14
Mixed method (qualitative & Quantitative)	2	29, 38
System Simulation	1	8

3.2 Period of Study and Nature of Intervention

The period of the studies was particularly during pandemic or referrals (Table 3). Seven studies evaluated resource allocation models. These include resource allocation criteria

in a hospital, ethical model for resource allocation, strategies to allocate resources during mass casualty, triage by resource allocation for hospitalized pediatric patients, model for prioritising scarce intensive care unit resources in the midst of COVID‑ 19, and resource allocation for congenital cardiac catheterization during the COVID-19 pandemic (1, 11, 12, 13, 14, 35, 36). Three studies evaluated provision of patient referral including simulation optimization methods for solving patient referral problems in hospital environment, challenges facing implementation of referral system for quality health care services, and provision of referral services at primary care (8, 29, 38).

Similarly, one study evaluated the Characteristics and outcomes of pediatric patients presenting at referral hospitals (15). On the other hand, another study proposed and validated a model for pediatric self-management (36). Table 4 illustrates the period and nature of the interventions identified.

Table 3: Intervention, Study Location, and Duration of the Study

Article	Country/study location	Period and Nature of Intervention
Bodina, et al (2017)	Italy	Resource allocation criteria in a hospital
Hassan (2019)	Iran	Artificial bee colony algorithm for solving fuzzy multi-objective bed allocation model
Knebel et al (2014)	USA	An ethical framework for allocating scarce medical resources to states during disasters
Timbie et al (2013)	USA	Strategies to manage and allocate scarce resources during mass casualty events
Lin, Taylor and Cohen (2018)	UK	Triage by Resource Allocation for hospitalized pediatric patients
Naidoo and Naidoo (2021)	South Africa	Framework for prioritising scarce intensive care unit resources in the midst of COVID‑ 19
Yore et al (2018)	Cambodia	Characteristics and outcomes of pediatric patients presenting at referral hospitals
Nango et al (2017)	Kenya	Determinants of a functional referral system in Kisumu County, Kenya patients' perspective
Morray et al (2021)	USA	Resource allocation for congenital cardiac catheterization during the COVID-19 pandemic
Modi et al (2012)	USA	A Framework for pediatric self-management
Nkonki et al (2017)	South Africa	Modelling the cost of community interventions to reduce child mortality
Alkinaidri and Alsulami (2018)	Saudi Arabia	Improving Healthcare Referral System Using Lean Six Sigma

Resource allocation strategies or models during emergencies and other relevant topics formed an integral part of all 12 interventions (1, 2, 8, 11, 12, 13, 14, 15, 29, 35, 36, 37, and 38). The resource allocation models discussed in the analysed studies were developed to solve the problem of distributing scarce resources during severe epidemics like Covid 19 (14, 35). Other resource allocation models were also developed to aid distribution of healthcare resources during various emergencies or disasters (1, 11, 12, and 14). Similarly, the interventions also presented studies related to optimization strategies or methods for solving the problems associated with patient referral (8, 15, 29, and 38). Finally, some of the analysed studies focused on resource allocation models for pediatric patients particularly during emergencies and referrals (13, 35, 36, and 37).

Similarly, two studies (12, 13) specifically used in-patient pediatric data (retrospective design) to formulate two models (simulation and disaster triage tool respectively) for determining diverse health indicators of children. In one study (12), Discrete Event Simulation was used to determine triage thresholds for probability of death and duration of ventilation as a function of casualty volume and the total number of available beds. Simulation was employed to compare survival between the proposed triage algorithm and a first come first served distribution of scarce resources. Greater survival of population was realised using the triage thresholds compared with a first come first served strategy. In this model, for five, six, seven, eight, and 10 thousand casualties, the triage algorithm increased the number of lives saved by 284, 386, 547, 746, and 1,089, respectively, compared with first come first served. In the other study, a disaster triage tool for the evacuation of hospitalized neonatal and pediatric populations was developed (13). This was employed to assess pediatric inpatients using bedside visual assessments and chart review to categorize patients transport level based on local emergency medical services protocols and expert opinion. Primary outcome was the number of each level of transport required for hospital evacuation. Secondary outcome was improved efficiency of obtaining information about specific transport needs for evacuation.

Two studies (14, 35) proposed resource allocation models for distributing scarce healthcare resources during the recent pandemic that continues to ravage the world to date, the Corona Virus (14). A model for regional triage committees adapted to the South African context consisting of the formation of Provincial multi-disciplinary Critical Care Triage

Committees was formed to alleviate the emotional, moral and legal burden on individual ICU teams and co-ordinate inter-facility collaboration using an adapted model (14). The mandate of the committee comprised of an impartial, broader and ethically sound viewpoint with time to consider broader contextual factors such as adjusting rationing criteria according to different levels of pandemic demand and the latest clinical evidence. Direct feedback to national level and accountability to a national monitoring committee strengthened the services of the committee. The study observed that no single ethical approach to decision-making is sufficient regarding resource allocation during Covid 19; instead, one, which considers multiple contextual factors, is necessary. Another study defined current patterns and provided guidance and recommendations on the preservation and repurposing of resources to help pediatric cardiac programs develop strategies for patient care during COVID-19 pandemic (35). The study found a relative uniformity among centers as to which procedures were considered elective. Only three centers had performed a catheterization on a confirmed COVID-19 positive patient. Centers located in areas with a higher number of COVID-9 cases have been more involved in a simulation of donning and doffing personal protective equipment (PPE) than low-prevalence centers.

Patient referral including models formulated for enhancing pediatric referral and associated challenges are discussed among the analysed articles (8, 15, 29, and 38). System simulation was used to construct a model and develop a simulation optimization method, combining the heuristic algorithm (patient referral mechanism) with the particle swarm optimization (PSO) method, to determine a better way to refer patients from one hospital (referring hospital) to another (recipient hospital) to receive certain imaging services (8). After the simulated model was verified and validated, three patient referral mechanisms to dispatch referring patients to the appropriate recipient hospitals were proposed. Based on the numerical results, the findings showed that Mechanism 2, transferring patients to the hospital with the shortest waiting time, had good performance in both scenarios: allowing patient referrals among all hospitals and limiting the patients' waiting time.

Another study observed the characteristics and outcomes of pediatric patients presenting at Cambodian referral hospitals without appointments (15). Predictors of admission included transfer or referral from another health provider, seeking prior care for the presenting problem, low socioeconomic status, onset of symptoms within 24h of seeking care, abnormal vital signs or temperature, and chief complaint of abdominal pain or fever. Similarly, challenges facing implementation of the referral system for quality health care services in Kenya was analysed (29). The study revealed that infrastructure, health information systems, capacity of health care workers, and financial resources were challenges in implementation of health care referral system. Another study investigated the factors that affect management of the referral system at the primary level of health care in Saudi Arabia (38). It showed that primary care facilities faced a number of challenges such as lack of referral transport, poor communication, lack of referral guidelines, shortage of skilled personnel, lack of diagnostic equipment and drugs, leading to the self-referral and the bypassing of primary care facilities.

The systematic review also revealed that only one study looked at pediatric mortalities and associated models to solve the problem (37). The study used the Lives Saved Tool (LiST), a model in the spectrum software, to estimate the costs and impact on reducing child mortality of scaling up interventions delivered by community health workers at community level from a provider's perspective. Results showed that a total of 9 interventions can prevent 8891 deaths by 2030. Hand washing with soap (21%) accounts for the highest number of deaths prevented, followed by therapeutic feeding (19%) and oral rehydration therapy (16%). The top 5 interventions account for 77% of all deaths prevented.

3.3 Discussions

This systematic review makes a unique contribution due to its explicit focus on models used for resource allocation decision making for scarce healthcare resources, with an aim of solving the problem of pediatric patient referral. The literature synthesised suggests that along with models based on algorithms, ethical considerations relating to cost saving, socio economic considerations, equity, patients and health systems play a role in the resource allocation decision-making. While it may not be fully possible to specifically highlight how resource allocation models have influenced referral of pediatric patients, it is worth isolating and examining them to understand how they have the potential to influence referral decision-making.

Variation of referral patterns and rates has drawn attention for some time now, although reasons for this are not fully understood, indicating they are varied, idiosyncratic and integral to the context. One of the notable findings is the small number of included studies, despite the inclusion of a broad date range, suggesting the impact of poor resource allocation decision making when referring pediatric patients for special care.

As highlighted by this review, a myriad of studies focusing on models for resource allocation have been conducted in response to crisis occasioned by pandemics. While such models may be useful in aiding referral processes, a huge amount of attention has been directed at Covid 19 (2, 3, 4, 6, 14). Of the studies on resource allocation models or models, distribution of mechanical ventilators is a major central focus in the discussions. This can stem from an obligation of responsibility for patients' wellbeing and unwillingness to take risks.

This systematic review has highlighted several models for allocating scarce healthcare resources. Some of the models include ethical model and logic model for decision making during catastrophic disasters. This model adapted medical triage and the federalism principle to the decision-making process for allocating scarce federal public health and medical resources (11). Another model is an algorithm to guide selection of patients for pediatric critical care admission during a severe pandemic when Crisis Standards of Care are implemented (12). Budget allocation decision in funding specific diseases has been guided based on allocative efficiency tools (9). Another model for evacuating neonatal and pediatric populations based on inpatients bedside visual assessments and chart review for categorizing patients transport level and local emergency medical services protocols as well as expert opinion (13). Besides models developed to aid resource allocation during health crisis, most models especially in Africa are triage based for minimizing disease burden (14).

This review points at the scarcity of documentations covering models for pediatric patient referral. This is in disregard of the fact that quiet a number of research have been documented on resource allocation models during specific crisis. The review has highlighted that pediatric patients account for 20–35% of all emergency hospital visits globally (15). It has also been highlighted in the review that children present a unique distribution of chief health complications compared to adults

and require diverse clinical management (16). Similarly, this review has revealed that child mortality remains a significant global health problem, with over 5 million deaths every year (17). Asia and sub-Saharan Africa have been identified in the review as regions with the highest number of child mortality rates (18). One area that requires development of suitable models for guiding resource allocation especially scarce healthcare resources is therefore the treatment of pediatric patients (19, 20).

Models for enhancing patient referral processes have also been highlighted in this review (8, 15, 29, and 38). These models have been aligned to heuristic algorithm (patient referral mechanism) with the particle swarm optimization (PSO) method, to determine a better way to refer patients from one hospital (referring hospital) to another (recipient hospital) to receive certain imaging services (8). Transferring patients to the hospital with the shortest waiting time is revealed as being appropriated among the reviewed studies, for allowing patient referrals among all hospitals and limiting the patients' waiting time (15, 29). The success of referral processes have been enumerated in the review to include low socioeconomic status

Another study observed the characteristics and outcomes of pediatric patients presenting at Cambodian referral hospitals without appointments (15). Predictors of admission included transfer or referral from another health provider, seeking prior care for the presenting problem, low socioeconomic status, onset of symptoms within 24h of seeking care, abnormal vital signs or temperature, and chief complaint of abdominal pain or fever. Similarly, challenges facing implementation of the referral system for quality infrastructure, health information systems, capacity of health care workers, and financial resources (29).

3.4 Implications for policy and practice

Internationally, health systems are struggling to meet the demand on emergency departments, with healthcare planners and managers endeavouring to reduce the strain by eliminating non-urgent resource utilization [3, 4]. Strengthening primary care capacity and capabilities, through strategies such as triage formation and scientifically modeled models such as bee algorithms or epistemic game theory, can contribute to decreasing child mortality especially in sub Saharan Africa (37, 38, 39). This could address the pattern of referrals at certain times of the day and week, highlighted in this review. Enhanced paediatric training for healthcare providers who experience professional uncertainty when treating children may lower referrals expenses due to an aversion of risk. An alternative strategy could be the provision of remote consultations for caregivers to seek advice from paediatricians. Stronger recognition of resource allocation methods and their impact on pediatric referral is also essential during care giver training. Greater awareness of various influences on referral decision-making is vital to ensuring appropriate and excellent care for patients (38).

3.5 Limitations

The findings of this review are limited primarily by the small number of included studies and the variation in study sample size. Literature on resource allocation models is mostly based on emergency situations and not normal cases of referral, and often does not focus specifically on pediatric patients. The focus of this review was empirical studies and therefore policy documents have not been included, though it is accepted that this may shed further light on referral pathways.

4. CONCLUSION

The decision to refer a child to a special care is imbued with a complex interplay of a healthcare system that is able to allocate the requisite resources in distributed health facilities. Enhanced awareness of healthcare resource availability on referral decision-making is crucial to understanding patterns of pediatric unscheduled healthcare and to planning services that respond to children's needs, whilst allowing primary healthcare providers to make decisions in the best interest of the child. Literature examining referral variation is rather scarce besides being outdated, suggesting up to date research is required to account for system changes in recent years. This review has identified scope for further research, such as qualitative research with pediatric specialists, which can contribute to understanding the inter-play between primary and emergency services, pertinent in the context of rising paediatric presentations to the healthcare.

5. ACKNOWLEDGMENTS

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