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Global Maternal and Child Health Outcomes: The Role of Obstetric Ultrasound in Low Resource Settings

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Abstract There are vast inequalities across maternal and infant mortality with the developing world accounting for the majority of the burden and within countries rural areas expecting worse outcomes than urban. These inequalities are linked to health care servicedelivery. This review focuses on obstetric ultrasound service and its potential to improve maternal and newborn health in low resource settings. A systematic search of English literature was conducted to identify current knowledge regarding use of ultrasound in low resource settings. Access to obstetric ultrasound in the developed world is almost universal. Access to obstetric ultrasound is instrumental in identifying potential obstetric risks, leading to improvements in maternal and newborn health outcomes. In contrast to this, access to obstetric ultrasound in the developed world is poor, particularly in rural areas. Innovations in teleradiology and portable ultrasound offer opportunity for improved ultrasound access in low resource settings, including opportunity for service coverage in rural and remote areas. The literature illustrates considerations for service provision in a broad range of settings in the developing world. Practical implications are vastly different in these settings and include infrastructure, economic resources, training and cultural acceptability. The versatility of ultrasound also offers a wide range of non-obstetric clinical applications. This review demonstrates promising benefits of obstetric ultrasound in poorly resourced settings with potential improvements in maternal and infant mortality and also highlights the need for large scale trials in these settings.

Keywords: *obstetric ultrasound, developing countries, maternal and child health, low resource settings*

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1. Introduction

Poor Maternal and Child Health (MCH) outcomes are a global, yet highly preventable problem [1,2]. Evidence informs that the developing world accounts for the majority of the maternal mortality burden. Half a million women died of complications related to pregnancy in 2005, half of these in Africa and another third in South East Asia [3]. Infant mortality is closely related and the trend is similar. About 3.1 million babies died before 28 days of age with 99% of these deaths occurring in middle and low income countries [3]. Maternal mortality is the health indicator that shows the widest gap between rich and poor, both between and within countries. In Africa the maternal mortality ratio is 620 per 100,000 live births compared to 14 per 100,000 live births in developed countries [4]. Within countries there are also disparities between urban and rural populations, with rural areas suffering worse outcomes [3,4,5].

MCH outcomes are related to health care service delivery (including prenatal, perinatal and postnatal services), socioeconomic, environmental and cultural factors [6,7,8]. Furthermore, it is well acknowledged that every pregnant woman and newborn is at risk and that quality obstetric care, safe delivery and access to essential obstetric services are necessary [9]. As a result of comprehensive health care services in the developed world, ultrasound is a routine part of obstetric care and anomalies in pregnancy can be detected early in gestation period. Potential life threatening complications such as fetal malpresentation, multiple gestations, ectopic pregnancy and placenta previa may be earlier identified and appropriately managed with the use of an ultrasound screening study [10]. This information, coupled with accurate gestational dating from ultrasound can assist in the management of pregnancies to allow the mother to reach appropriate obstetric care prior to delivery if a high risk pregnancy is identified [11]. In comparison, in the developing world the coverage of obstetric ultrasound is poor [12] and the opportunity to identify and manage risks during pregancy is limited to clinical examination or obstetric care may be non existent.

The potential to reduce maternal and neonatal deaths through the use of ultrasound is significant and addresses two of the Millennium Developments Goals (MDGs) including, (i) MDG 4 which aims to reduce child mortality, and (ii) MDG5 which aims to improve maternal health [13]. Improving the level of obstetric care is critical to address MCH outcomes and to accelerate progress toward achieving MDG 4and 5 targets.

The development of portable ultrasound units, in conjunction with teleradiology offers the opportunity to improve ultrasound access in low resource settings. There have been several trials in low resource settings that support the utility and benefit of ultrasound in the developing world. The evidence shows that maternal management is improved through the use of ultrasound to mitigate potential obstetric risks [10,11]. The considerations in this setting are many including practicalities such as electricity, physical infrastructure, referral and reporting pathways. Specific to the setting are considerations of cultural acceptance, local disease prevalence and availability of appropriate medical intervention. Training is a major factor in the success of an ultrasound service as the level of the diagnosis is dependent on the ability of the sonographer. Paramount to a useful and sustainable service is the establishment of locally provided training programs. The considerations for ultrasound in the developing world are vastly different to those in the developed world, hence the need for specific evidence.

This paper aims to identify the current knowledge regarding the use of obstetric ultrasound in low resource settings. It examines the potential utility of ultrasound services in these settings with the objective of providing information to practitioners, health policy makers and planners.

2. Methods

A systematic search of English literature was conducted to identify the current knowledge regarding the use of obstetric ultrasoundin low resources setting [14].

The following databases were searched: CINAHIL, ELDIS, MEDLINE, POPLINE MEDLINE (Ovid), Scopus, AIM, WHO (Statistical Information System) and Pro Quest. Hand searches were also conducted to identify the gray literature including searching for publications and reports from the World Health Organization and related Non-Governmental Organizations. Publications during the period of 10 years from 2002 to 2012 were eligible. The following search terms were used in combination and/or singly: ultrasound [*], maternal health [*], newborn [*], neonatal [*], developing countries [*], limited resource [*], obstetric [*], care [*], maternal deaths [*], child deaths[*].All titles and/or abstracts were screened to identify original publications. The search was extended by scrutinizing the references of selected articles and only articles for which the full text and abstract was available were considered. Due to the paucity of high quality information the search was extended by scrutinizing the references of selected articles to identify additional studies that may have been older than the timeframe stipulated including reviewing references cited in relevant publications. Because of the methodological complexity and limited number of articles providing high level of evidence, narrative including content analysis of articles as opposed to systematic review was conducted [15]. Major emerging themes were identified through recurrence in literature as well using our experiences and knowledge of public health related to this subject. Themes are summarized in Table 1 and described in the results section below.

3. Results

Table 1.Thematic grouping of articles

Citation	key theme
[Graham, Ahmed [1], Mahler [2], Campbell and Graham [6], Braveman and Tarimo [7], Ronsmans and Graham [8], Hofmeyr, Haws [16], WHO [17]]	Patterns in maternal and infant mortality
[Dewbury [10], Callen [18], Fox [19], D'Alton and Cleary-Goldman [20], Bricker, Neilson [21], Luck [22], Romosan, Henriksson [23]]	Obstetric ultrasound and maternal and neonatal health outcomes
[Harris and Marks [5], Kongnyuy and van den Broek [11], Carrera [12], Shah, Noble [24], Shah, Epino [25], Kotlyar and Moore [26], Firth, Mlay [27], Mindel [28], Blaivas, Kuhn [29], Adler, Mgalula [30], Bussmann, Koen [31], Gladstone, White [32], Geerts, Theron [33], Jha, Kumar [34], Rogo [35], Landis, Ananth [36]]	The use of ultrasound in the low resource setting
[Kumar, Uduman [9], Traisathit, Le Coeur [37]]	HIV and perinatal outcome

3.1. The Use of Ultrasound in Obstetric Services and Maternal Health Outcomes

In western medicine, obstetric ultrasound has achieved almost universal coverage and is a routine part of accepted antenatal care [11]. In developed countries it is common practice for pregnant women to receive two screening ultrasounds, with further scanning in high risk pregnancies. An ultrasound performed at 10-13 weeks is of benefit to confirm the presence of intrauterine pregnancy, excluding ectopic pregnancy [10,18]. Certain measurements are most accurately performed in this early time window. Detection of multiple gestations and determination of amnionicity and chorionicity is most accurately determined in the first trimester before 12 weeks gestation [19]. The importance of this is to allow for early risk stratification in multiple pregnancies, monochorionic twins are at increased risk of poor perinatal outcomes compared with dichorionic and if a planned reduction is performed knowledge of amnionicity and chorionicity is essential[6]. Furthermore, the most accurate time to measure gestational age is between 10 to 13 weeks by using a crown to rump measurement, at this time it is accurate +/- 5 days [20]. Accurate gestational age is of importance to reduce inductions for post term labor and to assess for intrauterine growth restriction. [20] It has been found that found that a policy of labor induction after 41 weeks compared to waiting indefinitely resulted in reduced perinatal death, illustrating the importance of accurate dating [21]. The measurement of the nuchal fold thickness measured between 11 and 13 weeks is used in conjunction with other markers to determine risk of Downs Syndrome [20].

A Cochrane review by Bricker [21] supports these conclusions, that early ultrasound results in better gestational age determination, earlier detection of multiple pregnancies and early discovery of fetal abnormalities. The outcome in the population studied by Bricker was a reduced failure to detect multiple pregnancies by 24 weeks and reduced induction for labor after 41 weeks. Bricker also notes that this evidence is collected in high resource

settings where overall levels of perinatal mortality are low and contribution of major fetal anomalies may be higher than in a low resource setting. This high fetal termination rate for abnormalities, combined with the possible higher cost of support of a severely disabled child in a developed country may make obstetric ultrasound more cost effective in developed countries. The cost and health benefits in a low resource setting will be specific to the setting.

Luck [22] carried out a UK study including 8849 patients over 4 years to assess the value of screening ultrasound carried out at 19 weeks. It is important to note that 90% of anomalies were detected in women with no risk factors. 140 fetal anomalies were detected, representing 1.9% of the population, 25 of these were lethal and led to termination of the pregnancy. Diagnosis of severe cardiac and gastrointestinal abnormalities influenced the place of delivery, assuring availability of specialized neonatal care immediately after delivery. Diagnosis of less severe anomalies such as renal dilatation resulted in earlier intervention post-delivery. A similar Swedish study by Romosan [23] reviewed 1102 routine ultrasound screening scans performed at 18 and 32 weeks, The study reported 68/1102 pregnancies terminated due to anomalies. The impact that false negative and false positive studies have on maternal mental health and potential risk of unwarranted terminations was also reported. This highlights the importance of quality audits and training procedures to be rigorous for ultrasound centers to minimize erroneous reports.

Long et al [38] conducted a study of 3529 pregnancies assessing the cost benefit of routine over high risk scanning at 18-20 weeks. Pregnancies considered high risk are those with a family history of congenital abnormalities, maternal risk factors such as age, drug and alcohol use, diabetes and biochemical markers for fetal abnormality. In the UK setting, it was found that the screening service was cost effective. Long [38] discusses cost savings of termination of severely abnormal fetuses. The cost of treating a severely handicapped child is significant, and these savings make the provision of a screening ultrasound service for fetal anomalies cost effective if the termination rate is sufficiently high. Clearly cost considerations will be different when considering these services in low resource settings. In addition to cost effectiveness of screening services ethical and emotional considerations must also be examined. A severely disabled child may have devastating on the rest of the family, prenatal recognition of abnormalities allows for counselling about termination. For this reason, morphology scanning must be provided in a setting with counselling services and, if appropriate, the availability of safe abortion facilities. Emotional and psychological costs and benefits of such a service are difficult to measure, but other benefits may be reassurance of a normal pregnancy, or emotional and practical preparation of delivery of a child with abnormalities.

A Cochrane review of use of ultrasound in early pregnancy (< 24 weeks) included 37505 women [39]. It was concluded that routine early pregnancy scanning allows for accurate assessment of gestational age, detection of multiple pregnancies and detection of fetal anomalies. In this study, the number of terminations for fetal anomalies increased. It is important to diagnose fetal anomalies prior to 24 weeks to allow for termination as it is safer during earlier pregnancy. The legalities for this will vary according to country. In France, for example, it is legal for termination at any time of pregnancy if there is a severe malformation [40].

Late pregnancy ultrasound is most often used selectively for high risk pregnancies. After 24 weeks ultrasound is used to monitor fetal growth; small for gestational age babies are at increased risk of still birth, large for gestational age increases the mother's risk of birth injury. Amniotic fluid measurements can be measured at late pregnancy which may affect birth management decisions. Some structural anomalies can manifest in late pregnancy, it has been postulated that to learn of such anomalies late stage could lead to optimal delivery, however it is argued that there is insufficient evidence to support this. [21] Placenta previa occurs in 0.5% of the pregnancies and is associated with considerable risk to the mother and baby. Respiratory distress syndrome and fetal anemia are the major causes of neonatal mortality and morbidity associated with placenta previa. Placenta previa also causes maternal morbidity due to abruption or post-partum hemorrhage. [10] Only 10% of pregnancies with placenta previa at the second trimester will remain at term. [21] In most pregnancies a clinical indication such as hemorrhage will occur to diagnose placenta previa. Fetal lie can also be assessed at this stage to diagnose breech presentation; however it was found that early diagnosis of a breech presentation did not reduce mortality or morbidity [21]. However, this result may be variable in the developing world where medical attention is not as readily accessible, or when geography dictates that the journey to a healthcare clinic must be planned well in advance. The conclusion of the Cochrane review assessing the use of routine late stage (> 24 weeks) scanning found that routine scanning on low risk, unselected population did not improve the outcome for mother or baby except for a statistically significant reduction in still birth rate due to placental grading. Often, in the developed world ultrasound scanning after 24 weeks gestation is used after identifying the risk at earlier appointments and is used where monitoring of the conditions above is required.

Screening ultrasound is cost effective in the developed world due to the high abortion rate of malformed fetuses. There is some debate and conflicting opinion in the literature regarding the benefit of ultrasound screening; however the benefit on high risk deliveries is that it improves patient management and perinatal outcome. National Institute of Clinical Evidence [41] recommends obstetric scanning at 10-13 weeks for gestational dating, determination of the number of and location of gestations and Down´s Syndrome screening if required. Scans at 18-20 weeks are for fetal structural anomalies, fetal lie and placental position. Further scanning can be carried out as appropriate if the pregnancy is deemed high risk. If the placenta extends across the internal cervical os at the 18-20 week scan a scan at 32 weeks should be offered.

3.2. Innovations in Ultrasound and Teleradiology and Practical Considerations

The first compact ultrasound machines were introduced approximately 12 years ago. Since then, compact ultrasound machines are becoming more compact and

durable. Many features of a full size machine, including Doppler are available on handheld units. In addition, the price of a compact unit is significantly less than for a full sized unit. Limitations in resolution of handheld machines may be mitigated in low resource settings by the prevalence of patients with low body fat [5].

Teleradiology is an area which can benefit the field of remote ultrasound where specialist care may not be close to the patient and where transporting the patient to medical care is difficult. Images can be sent by internet or on compact disk from the sonographer to a remote doctor or from a doctor to a specialist for a second opinion. This also has applications in training with reviews of scans and feedback on scan quality and technique. Telemedicine has the potential to reduce cost and improve efficiency of care not just in developing countries, but in the developed world.

Other innovations include the Imaging the World initiative [42] which has developed a low cost ultrasound program suitable for use in the developing world. The program uses a portable ultrasound which can transmit images via mobile phone. Imaging the World promotes ultrasound scanning using a volume rendering technique, which they suggest requires less training than traditional methods. A pilot program is underway in Uganda with planned expansion into regions in sub-Saharan Africa, India and China.

Improvements in affordability, durability, and portability have made ultrasound a viable imaging option for use in challenging geographical situations with limited infrastructure. It is important to consider the rural health gap in regards to ultrasound services, women and babies in rural areas have higher perinatal morality, [17] and portable ultrasound has the distinct advantage that it can be used to reach women in these areas. Ultrasound has the additional benefit over x-ray installations in that no room shielding or staff monitoring is required as it does not use ionizing radiation and the required consumables are low consisting of only ultrasound gel and print medium or data storage. Practical and logistical considerations for suitability of ultrasound in a low resource setting are very different to the high resource setting [28]. Many of these settings are remote, poorly accessible and have unreliable water and electricity, 80% of provincial African hospitals do not have a conventional electricity supply [12].

There are examples of successful installations in very challenging settings. Blavias [29] introduced a portable ultrasound scanner into the Amazon jungle and found that it ran reliably in the setting, providing a useful diagnostic tool. Similarly, Adler [30] introduced an ultrasound into a Tanzanian refugee camp and found that the machine ran reliably for the 2 year trial. Portability is further improved and problems with unreliable electricity supply mitigated through successful use of solar panels to charge portable ultrasound machines[5]. It is of benefit that the compact ultrasound units have an additional advantage in that they often bypass lengthy and expensive customs clearance due to their compact size [5].

In addition to imaging hardware and staff, other factors must be considered in the establishment of an ultrasound service and tailored to the local environment. These include referral pathways and clinical guidelines, image reporting availability, record keeping, quality assurance, availability of patient counselling and support. The provision of an ultrasound service must also be coupled with appropriate means to improve management as a result of the scan outcome. This may include access to safe abortion, or the provision to transfer a high risk pregnancy to a regional obstetric center. It should also be reiterated that the availability of a new technology such as ultrasound should complement and not detract from clinical diagnostic methods such as medical observation and history taking.

3.3. Clinicalevidence: Lessons from Poor Resource Settings

In 2005, the World Health Organisation (WHO) reported that severe bleeding (Haemorrhage), infections, eclampsia, obstructive labor, unsafe abortion and other direct and indirect causes account for the majority of maternal deaths. Haemaorrhage, obstructed labor and unsafe abortion account for a large proportion of these deaths [4] and ultrasound may assist in managing these risks. Maternal and new born mortality are closely linked. The number of babies dying before 28 days was 3.1 million in 2010, 99% of these deaths occuring in low and middle income countries. Of these deaths, prematurity and low birthweight account for 29% and birth trauma and asphyxiation 23%. Again the use of prenatal ultrasound has a role in the management of these risks [4].

Ultrasound is rarely available in the developing world where maternal and newborn mortality rates are starkly higher. [5] There are unreliable statistics regarding childbirth in Africa and only estimates are available. Part of the reason for this is that 71% of births are unregistered in Sub Saharan Africa. [12] The statistics for utilization of obstetric ultrasound are equally unreliable. In most of sub-Saharan Africa it is only in urban areas where 30% of pregnant women have an obstetric ultrasound. In rural areas, this figure is estimated to be 6% [5]. The development of compact ultrasound units which are portable, durable and inexpensive offers a great opportunity for reducing maternal and neonatal deaths in low resource settings [5].

Bussman [31] performed an assessment of 2309 patients seen in an ultrasound service in a district hospital in Botswana for a wide variety of referrals including obstetric, accounting for 741 of the scans. The most common obstetric pathologies diagnosed by ultrasound were spontaneous abortion, fetal demise, low lying placenta and ectopic pregnancy. It was found that the service was cost effective and improved patient management in 30% of cases. In Rwanda [24] a similar result was found, that the most common application was obstetric scans including determination of head position, gestational age and placental position. Management changed in 43% of patients seen in this clinic, and the service was affordable. A Liberian trial saw 102 patients in 5 weeks, the majority obstetric [26]. Similarly to the Botswana study pathologies scanned were evaluation of bleeding, fetal demise, gestational age determination, multiple gestation, and placenta previa, changing management in 62% of cases.

In Northern Tanzania a qualitative study assessed an obstetric service and role of ultrasound within the service [27]. Obstetricians in the practice reported that the major causes of mortality were that women frequently did not

know their estimated due date and they presented late with problems. They reported that ultrasound aided delivery management, pre-procedural planning and reduced pre and post term births. Barriers to implementing the service were that 80% of women presented for their first visit after 16 weeks pregnancy, and 33% presented after 24 weeks. Women involved in the trial found that knowing an estimated due date was helpful in planning a hospital delivery. This was important given that only 47% of deliveries in Tanzania occur in a health facility [27].

A study involving 1119 ultrasound scans in a hospital in Cameroon found the majority of referrals to be obstetric and gynecological. Of all scans, 78% were abnormal. The reason suggested for the high pathology rate was the late presentation of patients with illness due to the fear of medical costs, although patients without financial means are scanned for free in this hospital [43].

A study of 840 babies born in Malawi highlights the importance of the diagnosis of preterm birth. In sub-Saharan Africa, a baby born at 32 weeks has greatly diminished chance of survival [32]. The use of ultrasound to determine gestational age, and therefore diagnose preterm birth allows for intervention after birth to improve survival. Interventions include early implementation of breast feeding and antenatal corticosteroids. Compared to babies born at term as confirmed by ultrasound, those diagnosed pre term were almost twice as likely to die in their first two years of life.

Geerts [33] scanned 3009 women in a low resource setting in South Africa with a routine obstetric morphology scan. It was found that it did not improve neonatal or maternal outcome, however it did significantly reduce the need to refer women to a regional center for surveillance, and this was due to accurate gestational dating affecting management decisions. A reduction in perinatal mortality may occur when the ultrasound service has a high detection rate for fetal anomalies, followed by a high termination rate. This is strongly linked to the experience of the sonographer. [33] In view of limited resources in developing countries, the cost of a routine detailed morphology ultrasound would only be justifiable if it represented significant benefit to mother and child. It may be more feasible to offer a basic ultrasound service for risk stratification and gestational dating [33].

Ultrasound is likely to reduce the incidence of obstetric fistula thorough identifying pregnancies that are at increased risk to result in obstructed labor and encouraging access to a birthing center for delivery. It is estimated that 2 million women worldwide are living with an untreated obstetric fistula. This has a detrimental impact on quality of life and the identification of at risk pregnancies plays a role in reduction of this statistic [44].

A review article by Harris and Marks (2009) [5] summarizes anecdotal experience of ultrasound in limited resource settings. The authors deployed donated units in Serbia, Vietnam, Nicaragua, Tanzania, Kenya, Mali and Sierra Leone. The donations appear to have had a substantial impact on public health care, especially in maternal care. In Nicaragua local physicians report a reduction in maternal mortality from 12 deaths per year to 5 per year. In keeping with the other evidence, the authors believe that ultrasound in low resource settings can provide imaging to screen for placenta previa, fetal malposition, multiple gestation, ectopic pregnancy, obstructed labor, pelvic outlet measurement and limited fetal anatomy. Once diagnosed, patients with complicating conditions would then be transferred to a regional obstetric unit where they can be appropriately managed.

3.3.1. Fetal Sexing

In some countries, particularly China and India, ultrasound has introduced ethical issues with fetal sexing resulting in selective termination of female fetuses due to a preference for sons. Law prohibits this practice in both China and India, although the skewed gender ratio under five years of age in these populations suggests that this law is largely ignored. [34] Fetal sexing is an important consideration in the introduction of an ultrasound service and the relevance of this issue should be examined in a local context. Training should include the ethical use of ultrasound including potential misuse.

3.3.2. Abortion

Ultrasound plays a role in the reduction in abortion related mortality [35]. Worldwide, 13% of pregnancy related deaths are from abortion complications [4]. The complexities of this topic are not discussed here, but where abortion is medically provided ultrasound may provide a role in its safety and this may have relevance in the developing world. The Royal College of Obstetricians and Gynecologists [45], has recommended that gestation is routinely confirmed by ultrasound prior to termination. This is of particular importance between 1st and 2nd trimester, abortion during 1st trimester is safer so knowledge of gestational age will influence the choice of technology and skills, therefore improve the safety of the procedure [35]. The importance of ultrasound in provision of safe abortion is not only to assess stage of pregnancy, but also to check for multiple gestations which may influence procedural planning. Post procedure it plays a role to confirm complete abortion to address potential complications as a result of incomplete termination [35].

2.3.3. Maternal HIV

A study performed in Thailand used ultrasound dating for determining gestational age to assess pregnant women with HIV to prevent mother to child transmission. Alternatives to ultrasound such as measurement of fundal height and estimation of last menstrual period are also possible to determine gestational age in limited resource settings. It was found that in comparison to other methods ultrasound is the most accurate way to determine gestational age. Given that the ideal time to begin prophylactic therapy is 28 weeks gestation with accurate administration timing crucial to obtain the best outcome, ultrasound may play a role in this if available in the relevant setting [37].

3.4. Cultural Acceptability

A qualitative study in Northern Tanzania [27] examined cultural acceptance of a new ultrasound service. It was found that the majority of women desired an ultrasound, but had very limited understanding of what the procedure involved or the benefits from having it. Some women had misconceptions that the procedure would harm the child. In Tanzania there is a belief in witchcraft and spirits and their effect on pregnancy. This is also true in Botswana, The Gambia, and Zimbabwe. The authors of this study

describe a “medical pluralism” a model of health where medical technology and traditional beliefs exist side by side. As a result of this the practice of witchcraft was not a barrier to the acceptance of ultrasound. It was also seen that women had an overestimation of the diagnostic benefit of ultrasound; this was seen on Tanzania, Vietnam, Nigeria and Botswana. [27] This shows that, local research into pregnancy belief systems, education and management of expectations from ultrasound are important in the introduction of a new service. Interestingly, women taking part in this study stated that knowing an estimated due date was helpful for them to plan hospital delivery, and if this alters overall location of birthing there is potential for this behavioral change to benefit maternal and neonatal health.

In Tanzania abortion is illegal. This makes clinical and financial benefit of scanning for fetal anomalies reduce in comparison to countries where the woman may choose to terminate the pregnancy with the diagnosis of severe abnormality [5]. Birth of a child with serious fetal anomalies may have less significance in developed countries. For instance, in some African communities a child who doesn’t live beyond 40 days has never achieved “personhood”. [12] In addition the resources to treat a child with severe abnormalities may not be available, so the cost benefit of the service will differ to the developed world scenario. Abortion laws vary throughout the world which will dictate the clinical outcome of fetal anomaly diagnosis. This must also be kept in mind when planning relevance of diagnosis provided by ultrasound.

A report published in The Lancet [28] called for avoidance on a generic approach to introducing ultrasound services in the developing world. As shown, variances in local infrastructure and geography, cultural beliefs, training of staff, local disease patterns and financial resources are just some of the considerations when assessing feasibility of ultrasound in the developing world. Sustainability of an ultrasound service is reliant on adequate locally trained staff. In addition to this, available interventions based on the results of the ultrasound will be more limited than in the developed world. In countries where cultural requirements dictate a female sonographer this should also be considered in training of staff.

3.5. Training

The global shortage of more than 4 million trained health workers is most acute where maternal and perinatal mortality is highest, especially sub-Saharan Africa and South Asia. [16] Neonatal mortality and morbidity are inversely associated with coverage rates of skilled birth attendance. 60 million births occur annually outside of hospitals, 52 million without a skilled birth attendant. [16] Further to this, there are wide equity gaps between urban and rural areas. These statistics illustrate potential difficulties in providing skilled ultrasound users.

The quality of an ultrasound scan is dependent on the operator; the results depend crucially on the sonographer's knowledge and experience. Carrera [12] details sonographer training throughout Africa. 40.4% of operators have a short course in theory only, 38.3% have no training at all, only 14.9% have attended a practical course, but only 2.1% of these in a hospital environment. As a comparison, in Australia 2200 hours of hospital scanning experience are required to become an accredited sonographer. Mindel [28] advocates the strengthening of local training programs. Local training is more sustainable, and more affordable than sending physician abroad. It is suggested that improved ultrasound training at local medical schools and establishment of local practical training programs. Many clinics cannot afford to send doctors abroad to learn ultrasound, and constant rotation of visiting expatriate specialists may be unsustainable. [28] When establishing an ultrasound service the abilities of the sonographer dictates the service offered. A full fetal morphology scan takes considerably more experience to perform well than basic measurements such as gestational dating, fetal lie and placental position [12].

Ultrasound training can be offered to nontraditional users such as midwives and birth attendants and this was implemented successfully in a Thai refugee camp [46]. The workers in the clinic have been school educated to 16 years age, then undertaking a local 3 month ultrasound training program. Over 3000 women have been scanned in the clinic, and scanning reproducibility was examined in the study, which saw fetal growth measurements to be reproducible. Inter observer measurement error was assessed using the intra class correlation coefficient showing 0.99 for femur length measurement for trainees assessed against an expatriate doctor. Similarly, 4 day intensive ultrasound training course tailored to local pathologies was implemented in a Tanzanian refugee camp [30]. This program trained local doctors and was found in a 2 year follow up that the utilization and sustainability continued. In Rwanda a 9 week ultrasound training course was completed by local physicians. The course was provided by a US NGO after an assessment of local patient record to understand local disease patterns. The success of the 9 week course was highlights the benefit of appointing a local training coordinator to assure continuing professional education after completion of the program. [24] In all circumstances the diagnostic utilization should be tailored to the user’s expertise, incorrectly performed ultrasound can lead to the risk of mis-diagnosis.

Lack of training is a particular concern as it could result in idle equipment or incorrect use of equipment, possibly leading to an incorrect diagnosis and intervention. This highlights the need for establishment of training programs with ongoing skills maintenance to provide a safe service. Training should also include ethics, use and misuse of ultrasound, as well as good technique and implications to clinical care. Training in counselling and communication about the limitations and benefits of obstetric ultrasound is paramount to alleviate fear and manage expectations [11].

A number of ultrasound schools and ultrasound associations have opened in Africa in recent years. South Africa, Egypt and Libya have national Societies of Ultrasound. Regional societies include the African Society of Radiology, Mediterranean and African Society of Ultrasound and the West African Medical Ultrasound Society. Ultrasound training schools include Ian Donald School of Medical Ultrasound has branches in Egypt, Tunisia and Sudan and there are other African training schools in Tunisia, Rwanda and Uganda [12].

3.6. Utility of Ultrasound

The wide range of clinical applications for ultrasound and its safety make it well suited to use in the developing

world [28]. A study examining the utility of ultrasound in Liberia [26] found 53% of patients attended for obstetric and gynecological exams, followed by 14% for hepatobiliary. In a trial in Cameroon [43] 32% of referrals were gynecological, 15% obstetric and 19% hepatobiliary. In a Tanzanian refugee camp trial[30] 24% of exams were obstetric, 21.9% pelvic (including gynecological), 22.7% abdominal (including hepatobiliary) and 10% renal. In Rwanda 30% of exams were obstetric, 27% abdominal and 14% cardiac. [25] Similarly, in Botswana [31], obstetric examinations accounted for the majority of cases, followed by hepatobiliary. In all studies reviewed, obstetric and gynecological studies account for the majority of referrals, suggesting that ultrasound will be of particular benefit for women's health and obstetric care in the developing world. The patterns of referrals will be variable according to the population demographics and prevalent disease patterns.

Additionally, ultrasound has applications in some diseases specific to the developing world such as tropical diseases and management of HIV and tuberculosis. A Rwandan trial [25] demonstrated that ultrasound can be used for cardiac imaging in patients with HIV induced cardiomyopathy, TB related pericardial effusions and renal imaging in HIV related nephropathy. Ultrasound also has a role in the differential diagnosis of schistosomiasis, a disease prevalent predominantly in the developing world [3].

4. Discussion

This review provides evidence of the promising potential of the use of ultrasound in limited resource settings. Ultrasound is affordable, durable and has a wide range of applications making it suitable for limited resource settings. The emergence of compact ultrasound with solar panels and teleradiology greatly improves portability and the potential to improve coverage in rural areas. The importance to improve ultrasound coverage in rural areas in low resource settings is demonstrated by the access gap between rural and urban areas. In sub-Saharan Africa 30% of women in urban settings receive an obstetric ultrasound, in rural areas this drops to 6%. [12] In South Africa, the urban to rural gap is again demonstrated with 68% of women in urban areas receiving obstetric ultrasound, and only 18% in rural areas. [12]. This health care coverage inequity is reflected in poorer health outcomes for women in rural areas, reiterating the importance of targeted improved health service delivery in rural areas in low income countries.

There are a multitude of practical factors to consider when introducing ultrasound services; patient demographics, geographic factors, cultural beliefs, sonographer training, availability of appropriate interventions and prevalent disease patterns all play a role in the potential success of a service. Many of these factors may be peculiar to the developing world and the particular setting. The availability of trained staff is paramount to a successful and safe service and remains a considerable barrier to service provision in many low resource settings. Teleradiology is a step to improving access to expert knowledge with the possibility of remote consultations. As demonstrated, sustainable training programs and locally tailored services are also of prime importance.

Recommendations for obstetric care in low resource settings in the International Journal of Gynecology and Obstetrics [16] utilize ultrasound for several interventions including management of placenta previa, diagnosis of post term pregnancy and monitoring the position of the umbilical cord in breech presentation. It is reiterated that in the developed world ultrasound has greatly improved screening, diagnosis and management of placenta previa, currently a major cause of maternal mortality in the developing world. In this setting, diagnosis of placenta previa may be of more importance due to the distance from obstetric care in rural areas increasing time to access emergency care for maternal hemorrhage.

A further clinical consideration in ultrasound in the developing world is the need to develop local normal ranges, especially for fetal growth. Nomograms to compare normal growth rates of the fetus from the developed world may not be appropriate for use in the developing world. In low resource settings endemic malaria, maternal HIV, nutritional factors such as low pregnancy weight and low pregnancy weight gain lead to a lower average fetal weight. For this reason, it may be appropriate to customize nomograms to the local setting. This is of importance in the accurate diagnosis of intrauterine growth restriction in the low resource setting [36].

The literature demonstrates a need for large scale trials in these settings, particularly in rural and remote areas as strong statistical evidence is missing from the literature. This is of importance to assess the use of portable obstetric ultrasound, both as a screening tool and selectively and to determine the cost benefit and outcome on pediatric and maternal health.

5. Conclusions

In contrast to industrialized nations, childbearing remains perilous in the developing world. Trials have been conducted and found that ultrasound is utilized mostly in women's health for obstetric and gynecological applications when introduced in a limited resource setting. The clinical trials show that ultrasound has the potential to improve management of obstetric patients in the developing world, especially in risk stratification in late pregnancy. In this setting it is of particular benefit to assess number of gestations, fetal lie, placental position, estimated due date and fetal growth. In rural areas the time and distance to medical care further increases the need for risk stratification. The variance between ultrasound trials is seen as ultrasound is very operator dependent, this is seen also in trials in developed countries and highlights the importance of training to ensure maximum diagnostic utility and high levels of sensitivity and specificity.

There is limited data from large scale studies in low resource settings, particularly from rural settings. The evidence for the use of obstetric ultrasound in the developing world consists of many small trials, and anecdotal evidence, the results of which show improvements in patient management and health outcomes. Future directions should include large scale trials, particularly in rural areas to establish the use of ultrasound routinely and selectively to improve outcomes on maternal and fetal health. Other areas for future development are in

training, particularly research into establishment of recommendations for training in ultrasound in the developing world and availability of low cost practical training to a standardized level. Ultimately, ultrasound has great potential to reduce the maternal and neonatal mortality rate in the developing world and this potential needs to be further quantified. As such, it is plausible to conclude that ultrasound is also useful in the management of many non-obstetric conditions which makes this machine important tool to have in health service delivery in resource poor settings.

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