Investigating the use of ultrasonography for the antenatal diagnosis of structural congenital anomalies in low-income and middle-income countries: a systematic review

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ABSTRACT

Background Congenital anomalies are the fifth leading cause of under-5 mortality globally. The greatest burden is faced by those in low/middle-income countries (LMICs), where over 95% of deaths occur. Many of these deaths may be preventable through antenatal diagnosis and early intervention. This systematic literature review investigates the use of antenatal ultrasound to diagnose congenital anomalies and improve the health outcomes of infants in LMICs.

Methods A systematic literature review was conducted using three search strings: (1) structural congenital anomalies; (2) LMICs; and (3) antenatal diagnosis. The search was conducted on the following databases: Medline, Embase, PubMed and the Cochrane Library. Title, abstract and full-text screening was undertaken in duplicate by two reviewers independently. Consensus among the wider authorship was sought for discrepancies. The primary analysis focused on the availability and effectiveness of antenatal ultrasound for diagnosing structural congenital anomalies. Secondary outcomes included neonatal morbidity and mortality, termination rates, referral rates for further antenatal care and training level of the ultrasonographer. Relevant policy data were sought.

Results The search produced 4062 articles; 97 were included in the review. The median percentage of women receiving an antenatal ultrasound examination was 50.0% in African studies and 90.7% in Asian studies (range 6.8%–98.8%). Median detection rates were: 16.7% Africa, 34.3% South America, 34.7% Asia and 47.3% Europe (range 0%–100%). The training level of the ultrasound provider may affect detection rates. Four articles compared morbidity and mortality outcomes, with inconclusive results. Significant variations in termination rates were found (0%–98.3%). No articles addressed referral rates.

Conclusion Antenatal detection of congenital anomalies remains highly variable across LMICs and is particularly low in sub-Saharan Africa. Further research is required to investigate the role of antenatal diagnosis for improving survival from congenital anomalies in LMICs.

INTRODUCTION

Congenital anomalies are one of the leading causes of neonatal morbidity and mortality globally. The greatest burden of disease is faced by those in low/middle-income countries (LMICs), as 94% of congenital anomalies occur in these regions. Congenital anomalies comprise 9% of the total global burden of surgical disease and account for 57.7 million disability-adjusted life years lost annually across the globe. Recent estimates suggest that approximately 303 000 neonates die annually from congenital anomalies before reaching just 4 weeks of age. However, many experts believe that this is an underestimate, due to a lack of congenital anomaly registries and some neonates dying without a diagnosis or inclusion within current statistics.

The WHO defines congenital anomalies as either structural or functional abnormalities which occur during intrauterine development. Structural anomalies are physical abnormalities that occur when the organs or skeletal structure are improperly formed. These can often be detected on ultrasound antenatally and are the focus of this review. Some common structural congenital anomalies include heart defects, cleft lip and palate, neural tube defects, limb deformities and abdominal wall defects. Many structural anomalies require immediate surgical intervention at birth to avoid death or preventable disability. In such cases, antenatal diagnosis permits delivery at a centre where the appropriate surgical care can be provided on delivery, for example, gastroschisis where the intestines protrude through a hole in the abdominal wall at birth. In high-income countries (HICs), where the majority of cases...
are antenatally diagnosed, mortality is less than 5%, while in many LMICs, with limited antenatal diagnosis, the mortality rate can be as high as 100%.

The use of ultrasound technology in LMICs has significantly increased in recent years, as ultrasound machines have become more compact, transportable and affordable. Yet, a great number of congenital anomalies that can be detected antenatally via ultrasound go undiagnosed. Factors identified as barriers to effective antenatal ultrasound include limited training, equipment shortages, faulty ultrasound equipment and lack of maintenance services.

In recent years, higher global priority has been given to neonatal health. Sustainable development goal 3.2 aims to end all preventable under-5 deaths and reduce neonatal mortality in every country to 12 per 1000 live births. In 2010, the WHO released the 63rd World Health Assembly Report on Birth Defects, recommending ‘prevention whenever possible, to implement screening programs and to provide care and ongoing support to children with birth defects and their families’.

To develop a better understanding of antenatal ultrasound provision in LMICs, this study aimed to systematically investigate the availability and effectiveness of antenatal ultrasound in the diagnosis of structural congenital anomalies in LMICs. It further aimed to evaluate the effects of antenatal ultrasound diagnosis on mortality and morbidity outcomes, termination rates and referral for further antenatal care and management planning. Additionally, it assessed the level of training of ultrasonographers undertaking antenatal scans and relevant antenatal ultrasound policies in LMICs. This information is vital to help clarify the existing disparities in antenatal ultrasound provision and the potential benefits for improved health outcomes.

**METHODOLOGY**

Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines have been followed when conducting this systematic review (online supplementary file 1). A protocol for this systematic review was published in *BMJ Paediatrics Open*.

**Search strategy**

A search was conducted using three search strings: (1) structural congenital anomalies, (2) LMICs and (3) antenatal diagnosis using ultrasound (online supplementary file 2). Using the Ovid programme, an electronic database search was conducted on Medline, Embase, PubMed and the Cochrane Library. These searches were filtered to only include studies with human subjects. An example of the search in Medline can be found in online supplementary file 3. Only fetuses with a structural congenital anomaly as listed in search string 1 were included. Only studies from LMICs were included; these were limited to the English language. Studies with less than five patients were excluded. A further search was conducted on the WHO website to identify relevant grey literature, particularly related to antenatal ultrasound policy. The following terms were searched in the WHO Reproductive Health Library: ultrasound, ultrasonography, congenital anomalies, congenital abnormalities, congenital anomaly, congenital abnormality, birth defect, antenatal detection, prenatal detection, antenatal diagnosis and prenatal diagnosis. Following the search of each term, the results were expanded using a snowball strategy to optimise the inclusion of all relevant data.

**Study design**

All forms of evidence-based research were included. This includes systematic reviews, meta-analyses, randomised controlled trials, descriptive observational studies, case-control studies, cohort studies and case series.

**Methodological quality**

Although the researchers intended to use the Cochrane Risk of Bias for Non-Randomised Studies of Interventions and the revised tool to assess Risk of Bias in Randomised Trials V.2.0 to evaluate methodological quality, the majority of studies included in this systematic review were not interventional studies. Overall, the data were heterogeneous and descriptive in nature, which was not suitable for existing quality assessment tools.

**Study screening**

References produced from the search results were added to EndNote V.X8 and duplicates were removed. The articles were then uploaded to Covidence and screened in
duplicate. Articles that did not meet the study criteria were removed.

**Data extraction and synthesis**

Data extraction was undertaken by the principal investigator. The data extraction table can be found in online supplementary file 4. The primary analysis focused on the availability and effectiveness of antenatal ultrasound for structural congenital anomalies. Secondary outcomes included neonatal morbidity and mortality, termination rates and referral rates for further antenatal care. The results are presented in tables and descriptive statistics (range and median) have been calculated regionally.

**Patient and public involvement**

Given that this is a systematic literature review, there was no patient or public involvement for the collection of data and literature review. Public involvement will be important for prioritising antenatal ultrasound on the political agenda and improving antenatal care programmes. To disseminate the results of this study, international charities and organisations involving structural congenital anomalies will be approached to assist in circulation.

**RESULTS**

**Study screening**

The search produced 4062 articles. Of these, 745 duplicates were removed. The remaining 3317 articles underwent abstract and title review by two independent reviewers. Of the 3317 articles screened, 2826 were excluded. Four hundred and ninety-one articles were then reviewed by two independent reviewers in full text. At this stage, 316 articles were excluded; 73 for non-English language (online supplementary file 5).

One hundred and seventy-five articles were found to meet all inclusion criteria listed in the search strings. Of these, 78 provided no data relevant to the study and thus were excluded. Ninety-seven studies were included in the data extraction phase (figure 1). Although all LMICs as defined by the World Bank were included in the search, not all countries yielded results in the text screening. One hundred and thirty-eight LMICs were included in the literature search; however, only 29 countries (21%) had any data that met the inclusion criteria (figure 2, online supplementary file 6).

It is also notable that the majority of included studies were conducted on an institutional level. Thus, while the data from these studies provide important information from the countries of this review, they are by no means a representative sample of an entire country or even an entire city. Each article also varied widely in the information it provided, ranging from antenatal detection rates to policy analysis. Given the heterogeneity of data extrapolated from these articles, it was not feasible to perform a meta-analysis.

**Percentage of women receiving antenatal ultrasound**

Twenty-one studies (12 retrospective and 9 prospective observational studies) in 12 countries provided data on this (table 1). There was significant variation in the percentage of women receiving antenatal ultrasound scans, ranging from 6.8% in a Tanzanian study to 98.8% in a study from China. The data suggest a particularly low rate of women receiving antenatal ultrasound in Africa, with a median of 50.0% compared with 90.7% in Asia. No studies were conducted in Europe or South America, and only one study was conducted in North America (Jamaica, 98.2%).

**Effectiveness of antenatal ultrasound**

Sixty-five studies (46 retrospective and 18 prospective observational studies and a parent survey) in 22 countries provided data on detection rates (table 2). Detection rates varied widely across studies, from 0% to 100%, with...
| Author(s)                              | Study location | Study type                          | Study population                                                                 | # of women in study | # of women who received antenatal ultrasound (%) |
|---------------------------------------|----------------|-------------------------------------|---------------------------------------------------------------------------------|--------------------|-----------------------------------------------|
| de Paul Djientcheu et al<sup>22</sup> | Cameroon       | Retrospective descriptive observational study | Institutional; patients with NTDs admitted to neonatology unit                   | 69                 | 27 (39.1%)                                    |
| Abdur-Rahman et al<sup>23</sup>       | Nigeria        | Retrospective descriptive observational study | Institutional; patients with abdominal wall defects at a tertiary health centre in the North-Central geopolitical zone of Nigeria | 56                 | 51 (91.1%)                                    |
| Adeleye et al<sup>24</sup>            | Nigeria        | Prospective cross-sectional study     | Institutional; patients presenting with major CNS anomalies at tertiary hospital | 54                 | 43 (79.6%)                                    |
| Adeleye and Joel-Medewase<sup>25</sup> | Nigeria        | Retrospective cross-sectional survey  | Institutional; patients with CNS defects at a neurosurgeon’s practice            | 151                | 91 (60.3%)                                    |
| Bankole et al<sup>26</sup>            | Nigeria        | Prospective descriptive observational study | Institutional; patients presenting with CNS anomalies at tertiary hospital       | 108                | 54 (50%)                                      |
| Idowu and Olawehinmi<sup>27</sup>     | Nigeria        | Prospective descriptive observational study | Institutional; patients with NTDs at tertiary hospital                           | 94                 | 91 (96.8%)                                    |
| Okafor et al<sup>28</sup>             | Nigeria        | Prospective cohort study             | Institutional; patients with PUV at tertiary hospital                           | 31                 | 22 (71%)                                      |
| Sekabira and Hadley<sup>29</sup>      | South Africa   | Retrospective descriptive observational study | Institutional; patients with gastroschisis at tertiary hospital                  | 106                | 25 (23.6%)                                    |
| Santos et al<sup>30</sup>             | Tanzania       | Prospective descriptive observational study | Institutional; patients with hydrocephalus at tertiary medical facility          | 125                | 9 (6.8%)                                      |
| Wesonga et al<sup>31</sup>            | Uganda         | Prospective cohort study             | Institutional; patients with gastroschisis at a tertiary hospital                | 41                 | 10 (24.4%)                                    |
| Munjanja et al<sup>32</sup>           | Zimbabwe       | Prospective descriptive observational study | Institutional; all patients delivered at Greater Harare Obstetric Unit           | 36 514             | 4429 (12.1%)                                  |
| **Total**                             |                |                                     |                                                                                 | 37 349             | 4852 (50%)                                    |

**Asia**

| Author(s)     | Study location | Study type                          | Study population                                                                 | # of women in study | # of women who received antenatal ultrasound (%) |
|----------------|----------------|-------------------------------------|---------------------------------------------------------------------------------|--------------------|-----------------------------------------------|
| Lu et al<sup>33</sup> | China         | Retrospective cross-sectional study | National; fetuses with NTDs                                                       | 424                | 419 (98.8%)                                   |
| Bhat et al<sup>34</sup> | India         | Retrospective descriptive observational study | Institutional; patients admitted to NICU with CDH<sup>*</sup>                  | 16                 | 11 (68.8%)                                    |
| Raman et al<sup>35</sup> | India         | Retrospective descriptive observational study | Institutional; symptomatic patients with congenital cystic lung lesions at tertiary care centre | 40                 | 6 (15%)                                       |

Continued
| Author(s)          | Study location | Study type                      | Study population                                                                 | # of women in study | # of women who received antenatal ultrasound (%) |
|-------------------|----------------|---------------------------------|----------------------------------------------------------------------------------|---------------------|-----------------------------------------------|
| Saha et al<sup>36</sup> | India          | Retrospective descriptive observational study | Institutional; all deliveries at rural medical college                           | 7365                | 6682 (90.7%)                                 |
| Sood et al<sup>37</sup> | India          | Retrospective descriptive observational study | Institutional; patients with NTDs at tertiary hospital                           | 65                  | 44 (67.7%)                                   |
| Kazmi et al<sup>38</sup> | Iran           | Prospective descriptive observational study | Institutional; patients referred to tertiary centre for myelomeningocele evaluation and management | 140                 | 136 (97.1%)                                  |
| Samadirad et al<sup>39</sup> | Iran           | Retrospective descriptive observational study | Regional; fetuses with congenital anomalies                                      | 639                 | 557 (87.2%)                                  |
| Ho et al<sup>40</sup>     | Malaysia        | Retrospective cohort study       | Regional; births in Kinta District (253 cases with congenital anomalies and 506 control cases) | 759                 | 705 (92.9%)                                  |
| Kitisomprayoonkul and Tongsong<sup>41</sup> | Thailand       | Prospective descriptive observational study | Institutional; patients with NTDs at tertiary hospital                           | 46                  | 42 (91.3%)                                   |
| **Total**            |                |                                 | 9 studies, 5 countries; 7 retrospective, 2 prospective observational studies       | 9494                | 8602 Median: 90.7%; Range: 15%–98.8%        |
| **North America**    |                |                                 |                                                                                  |                     |                                               |
| Johnson et al<sup>42</sup> | Jamaica       | Retrospective observational review | Institutional; patients with congenital anomalies at tertiary hospital           | 55                  | 54 (98.2%)                                   |
| **Total**            |                |                                 | 1 study, 1 country; 1 retrospective observational study | 55                  | 54 Median: N/A; Range: N/A                   |

CDH, congenital diaphragmatic hernia; CNS, central nervous system; NICU, neonatal intensive care unit; NTD, neural tube defects; PUV, posterior urethral valves.
Table 2  Effectiveness of antenatal ultrasound

| Author(s)                  | Study location | Study type                        | Study population                                                                 | # of women in study | # of women who received antenatal diagnosis (%) |
|----------------------------|----------------|-----------------------------------|----------------------------------------------------------------------------------|---------------------|-----------------------------------------------|
| **Africa**                 |                |                                   |                                                                                  |                     |                                               |
| de Paul Djientcheu et al   | Cameroon       | Retrospective descriptive         | Institutional; patients with NTDs admitted to neonatology unit                    | 27                  | 8 (29.6%)                                     |
|                            |                | observational study               |                                                                                  |                     |                                               |
| Sorri and Mesfin           | Ethiopia       | Retrospective cross-sectional      | Multicentre; patients with NTDs at two tertiary hospitals                        | 177                 | 127 (71.8%)                                   |
| Abdur-Rahman et al         | Nigeria        | Retrospective descriptive         | Institutional; patients with abdominal wall defects at a tertiary health centre in the North-Central geopolitical zone of Nigeria | 56                  | 1 (1.8%)                                      |
| Adeleye et al              | Nigeria        | Prospective cross-sectional       | Institutional; patients presenting with major CNS anomalies at tertiary hospital | 43                  | 6 (14%)                                       |
| Adeleye and Joel-Medwase   | Nigeria        | Retrospective cross-sectional      | Institutional; patients presenting with CNS anomalies at a neurosurgeon's practice | 146                 | 26 (17.8%)                                    |
| Akinmoladun et al          | Nigeria        | Prospective descriptive           | Institutional; patients attending clinic for ultrasound screening                 | 16                  | 15 (93.8%)                                    |
| Amadi and Eghwrudjakpor    | Nigeria        | Retrospective descriptive         | Institutional; all patients with encephalocele at tertiary hospital              | 17                  | 5 (29.4%)                                     |
| Bankole et al              | Nigeria        | Prospective descriptive           | Institutional; patients presenting with CNS anomalies at tertiary hospital       | 108                 | 0 (0%)                                        |
| Idowu and Olawehinmi       | Nigeria        | Prospective descriptive           | Institutional; patients presenting with NTDs at tertiary hospital                | 91                  | 23 (25.3%)                                    |
| Okafo et al                | Nigeria        | Prospective cohort                | Institutional; patients with PUV at tertiary hospital                             | 31                  | 2 (6.5%)                                      |
| Choopa et al               | South Africa   | Retrospective descriptive         | Institutional; patients with PUV at paediatric nephrology unit                   | 60                  | 10 (16.7%)                                    |
| Sekabra and Hadley         | South Africa   | Retrospective descriptive         | Institutional; patients with gastroschisis at tertiary hospital                  | 106                 | 13 (12.3%)                                    |
| Chanoufi et al             | Tunisia        | Retrospective case series (6 cases)| Institutional; cases of acardiac twins at maternity centre                        | 6                   | 1 (16.7%)                                     |
| Wesonga et al              | Uganda         | Prospective cohort                | Institutional; patients with gastroschisis at a tertiary hospital                 | 41                  | 1 (2.4%)                                      |
| Munjanja et al             | Zimbabwe       | Prospective descriptive           | Institutional; patients with congenital anomalies at obstetrical unit             | 91                  | 46 (50.5%)                                    |
| Total                      | 15 studies, 7  | 8 retrospective, 7                | 14 institutional, 1 multicentre                                                  | 1016                | 284                                           |
|                            | countries      | prospective observational         | studies                                                                         |                     |                                               |

Asia
| Author(s)          | Study location | Study type                                      | Study population                                                                 | # of women in study | # of women who received antenatal diagnosis (%) |
|-------------------|----------------|-----------------------------------------------|-----------------------------------------------------------------------------------|---------------------|-----------------------------------------------|
| Deng et al         | China          | Retrospective cross-sectional study           | National; patients with omphalocele as reported in Chinese national birth defects monitoring network 1996–2006 | 827                 | 322 (38.9%)                                  |
| Hong et al         | China          | Retrospective cohort study                    | Multicentre; patients with gastroschisis                                           | 17                  | 3 (17.6%)                                     |
| Liao et al         | China          | Retrospective descriptive observational study | Institutional; patients with limb abnormalities at maternity and child health hospital | 36                  | 28 (77.8%)                                   |
| Liu et al          | China          | Retrospective cross-sectional study           | Institutional; patients with congenital anomalies at a tertiary hospital            | 233                 | 71 (30.5%)                                   |
| Lu et al           | China          | Retrospective cross-sectional study           | National; patients with NTDs                                                        | 424                 | 361 (85.1%)                                  |
| Shi et al          | China          | Retrospective descriptive observational study | Institutional; cases of conjoined twins at tertiary hospital                       | 7                   | 4 (57.1%)                                     |
| Weng et al         | China          | Retrospective descriptive observational study | Institutional; patients with congenital choledochal cyst at specialty women’s hospital | 21                  | 19 (90.5%)                                   |
| Bhat et al         | India          | Retrospective descriptive observational study | Institutional; patients admitted to NICU with CDH                                  | 16                  | 4 (25%)                                       |
| Kumar et al        | India          | Retrospective descriptive observational study | Institutional; symptomatic patients with congenital bronchopulmonary anomalies     | 25                  | 2 (8%)                                        |
| Raman et al        | India          | Retrospective descriptive observational study | Institutional; symptomatic patients with congenital cystic lung lesions at tertiary care centre | 40                  | 3 (7.5%)                                     |
| Rattan et al       | India          | Retrospective descriptive observational study | Institutional; patients operated on for oesophageal atresia and tracheoesophageal fistula at a tertiary care centre | 693                 | 63 (9.1%)                                    |
| Sanghvi et al      | India          | Prospective descriptive observational study   | Institutional; patients with renal anomalies at tertiary centre                     | 125                 | 65 (52%)                                      |
| Sarin et al        | India          | Retrospective case series (18 cases)          | Institutional; patients with duodenal webs at tertiary hospital in India             | 18                  | 2 (11.1%)                                     |
| Sharada et al      | India          | Retrospective descriptive observational study | Institutional; patients diagnosed with unilateral multicystic dysplastic kidney at tertiary hospital | 47                  | 34 (72.3%)                                   |
| Singh et al        | India          | Retrospective descriptive observational study | Institutional; patients with unilateral multicystic dysplastic kidney at tertiary centre | 22                  | 12 (54.5%)                                   |
| Solanki et al      | India          | Retrospective case series (6 cases)           | Institutional; patients diagnosed with crossed fused renal ectopia at tertiary hospital | 6                   | 1 (16.7%)                                     |
| Kazmi et al        | Iran           | Prospective descriptive observational study   | Institutional; patients referred to tertiary centre for myelomeningocele evaluation and management | 136                 | 33 (24.3%)                                   |
| Author(s)          | Study location | Study type                                                                 | Study population                                                                 | # of women in study | # of women who received antenatal diagnosis (%) |
|-------------------|----------------|----------------------------------------------------------------------------|---------------------------------------------------------------------------------|---------------------|-----------------------------------------------|
| Mirshemirani et al | Iran           | Retrospective descriptive observational study                            | Institutional; patients treated for PUV at a tertiary hospital                  | 98                  | 20 (20.4%)                                    |
| Shahkar et al     | Iran           | Retrospective descriptive observational study                            | Institutional; patients with congenital pulmonary mass at a tertiary hospital   | 47                  | 10 (21.3%)                                    |
| Ho et al          | Malaysia       | Retrospective cohort study                                                | Regional; births in Kinta District (253 cases with congenital anomalies and 506 control cases) | 252             | 37 (14.7%)                                    |
| Munim et al       | Pakistan       | Retrospective cohort study                                                | Institutional; patients with diaphragmatic hernia at tertiary hospital          | 65                  | 41 (63.1%)                                    |
| Kitisomprayoonkul and Tongsong | Thailand | Prospective descriptive observational study                            | Institutional; patients with NTDs at tertiary hospital                         | 42                  | 42 (100%)                                     |
| Pitukkijronnakorn et al | Thailand | Prospective cross-sectional study                                      | Institutional; patients diagnosed with major congenital anomalies at tertiary hospital | 316             | 144 (45.6%)                                   |
| Srisupundit et al | Thailand       | Prospective descriptive observational study                              | Institutional; patients undergoing antenatal ultrasound at a university teaching hospital in Chiang Mai | 34                  | 24 (70.6%)                                    |
| Total             | 24 studies, 6 countries | 19 retrospective, 5 prospective observational studies | 20 institutional, 1 multicentre, 1 regional, 2 national                          | 3547               | 1345 Median: 34.7% Range: 7.5%–100%          |
| **Europe**        |                |                                                                            |                                                                                 |                     |                                               |
| Iliescu et al     | Romania        | Prospective descriptive observational study                              | Multicentre; patients at two institutions with major congenital anomalies      | 76                  | 74 (97.4%)                                    |
| Ognean et al      | Romania        | Retrospective case series (7 cases)                                       | Institutional; patients with oesophageal atresia at a tertiary centre            | 7                   | 0 (0%)                                        |
| Tarca and Aprodu  | Romania        | Retrospective descriptive observational study                            | Institutional; patients with omphalocele at tertiary hospital                   | 105                 | 14 (13.3%)                                    |
| Tarca and Aprodu  | Romania        | Retrospective descriptive observational study                            | Institutional; patients with gastroschisis at tertiary hospital                 | 54                  | 9 (16.7%)                                     |
| Tarca et al       | Romania        | Retrospective descriptive observational study                            | Institutional; patients with gastroschisis at tertiary hospital                 | 114                 | 13 (11.4%)                                    |
| Tudorache et al   | Romania        | Retrospective descriptive observational study                            | Institutional; patients with cases of left-sided CDH at tertiary hospital       | 21                  | 11 (52.4%)                                    |
| Postoev et al     | Russia         | Retrospective cross-sectional study                                       | Regional; patients with congenital anomalies in the Kola Peninsula (data from two birth defect registries) | 232             | 81 (34.9%)                                    |
| Aygun et al       | Turkey         | Retrospective descriptive observational study                            | Institutional; patients with NTDs at tertiary hospital                          | 100                 | 72 (72%)                                      |

Table 2 Continued
### Table 2: Continued

| Author(s)          | Study location                  | Study type                          | Study population                                                                 | # of women in study | # of women who received antenatal diagnosis (%) |
|--------------------|--------------------------------|-------------------------------------|----------------------------------------------------------------------------------|---------------------|-----------------------------------------------|
| Dane et al<sup>74</sup> | Turkey                         | Prospective descriptive observational study | Institutional; fetuses with incurable congenital anomalies and curable severe congenital anomalies at a training and research hospital | 24                  | 23 (95.8%)                                    |
| Orgul et al<sup>75</sup>    | Turkey                         | Retrospective descriptive observational study | Institutional; patients with gastrointestinal tract malformations at a university children's hospital | 56                  | 34 (60.7%)                                    |
| Oztekin et al<sup>76</sup>   | Turkey                         | Prospective descriptive observational study | Institutional; patients with a major structural congenital anomaly at an obstetrics and gynaecology teaching hospital | 21                  | 19 (90.5%)                                    |
| Sahinoglu et al<sup>77</sup> | Turkey                         | Retrospective case series (6 cases)   | Institutional; patients with limb body wall complex at a women and children's research hospital | 6                   | 5 (83.3%)                                     |
| Tabel et al<sup>78</sup>     | Turkey                         | Prospective descriptive observational study | Institutional; patients with kidney or urinary tract anomalies at a university hospital | 76                  | 32 (42.1%)                                    |
| Taskapilioglu et al<sup>79</sup> | Turkey                        | Retrospective descriptive observational study | Institutional; patients with open spina bifida at tertiary centre | 78                  | 26 (33.3%)                                    |
| **Total**              | **14 studies, 3 countries**    | **10 retrospective, 4 prospective observational studies** | **12 institutional, 1 multicentre, 1 regional**                                      | **970**             | **413 Median: 47.3% Range: 0%–97.4%**         |

**North America**

| Author(s)          | Study location                  | Study type                          | Study population                                                                 | # of women in study | # of women who received antenatal diagnosis (%) |
|--------------------|--------------------------------|-------------------------------------|----------------------------------------------------------------------------------|---------------------|-----------------------------------------------|
| Johnson et al<sup>42</sup> | Jamaica                        | Retrospective descriptive observational study | Institutional; patients with congenital anomalies at a tertiary hospital           | 57                  | 44 (77.2%)                                    |
| **Total**              | **1 study, 1 country**          | **1 retrospective observational study** | **1 institutional study**                                                         | **57**              | **44 Median: N/A Range: N/A**                 |

**South America**

| Author(s)          | Study location                  | Study type                          | Study population                                                                 | # of women in study | # of women who received antenatal diagnosis (%) |
|--------------------|--------------------------------|-------------------------------------|----------------------------------------------------------------------------------|---------------------|-----------------------------------------------|
| Campana et al<sup>80</sup>   | Argentina, Brazil, Chile, and Venezuela | Prospective descriptive observational study | Multicountry; patients with congenital anomalies in 18 Latin American hospitals | 812                 | 457 (56.3%)                                    |
| Germani et al<sup>81</sup>   | Argentina                       | Retrospective descriptive observational study | Institutional; patients with choledochal cyst at a private hospital               | 12                  | 4 (33.3%)                                     |
| Wyszynski et al<sup>82</sup> | Argentina                       | Survey                              | Institutional; patients with non-syndromic oral cleft (collected from parents’ survey data) | 165                 | 7 (4.2%)                                      |
| Carvalho et al<sup>83</sup>  | Brazil                          | Prospective cohort study            | Institutional; patients with major congenital anomalies at a tertiary hospital     | 130                 | 93 (71.5%)                                    |
| Luiza et al<sup>84</sup>     | Brazil                          | Retrospective cross-sectional study  | Institutional; patients with oro-facial cleft at a specialised society attending to cleft patients | 168                 | 7 (4.2%)                                      |
| Author(s)       | Study location | Study type                          | Study population                                                                 | # of women in study | # of women who received antenatal diagnosis (%) |
|-----------------|----------------|-------------------------------------|------------------------------------------------------------------------------------|---------------------|-----------------------------------------------|
| Tannuri et al   | Brazil         | Retrospective descriptive observational study | Multicentre; patients with gastroschisis at three tertiary centres                  | 163                 | 134 (82.2%)                                   |
| Vilela et al    | Brazil         | Retrospective cross-sectional study   | Institutional; patients with gastroschisis at a tertiary hospital                    | 31                  | 10 (32.3%)                                    |
| Correa et al    | Colombia       | Retrospective case-control study      | City-wide; data from Bogota Congenital Malformations Surveillance Program           | 167                 | 82 (49.1%)                                    |
| de Rovetto et al| Colombia       | Retrospective descriptive observational study | City-wide; patients with congenital renal agenesis at centres in Cali, Colombia    | 38                  | 8 (21.1%)                                     |
| Rosselli et al  | Colombia       | Retrospective descriptive observational study | City-wide; patients with congenital talipes equinovarus in Bogota, Colombia        | 178                 | 61 (34.3%)                                    |
| Saldarriaga et al | Colombia  | Retrospective cross-sectional study   | City-wide; patients with congenital anomalies diagnosable by antenatal ultrasound in NICUs of Cali, Colombia | 217                 | 117 (53.9%)                                   |
| **Total**       | 11 studies, 5 countries | 8 retrospective, 2 prospective observational studies, 1 survey | 5 institutional, 1 multicentre, 4 city-wide, 1 multicountry                          | 2078                | 980 Median: 34.3% Range: 4.2%–82.2%          |

CDH, congenital diaphragmatic hernia; CNS, central nervous system; NICU, neonatal intensive care unit; NTD, neural tube defects; PUV, posterior urethral valves.
with little correlation according to geographical region or type of anomaly. In Africa, the median detection rate was 16.7%, which is low compared with other LMICs, with 34.3% in South America, 34.7% in Asia and 47.3% in Europe. There was only one study from North America (Jamaica, 77.2%). Of the studies conducted from Africa, 8 of the 15 were in Nigeria and hence may not be representative of the whole region.

### Training of personnel performing ultrasound examination

Fifteen of the studies detailed the training of the personnel providing the ultrasound scans (Table 3). Several of the included studies mentioned that the scans were performed by ‘experienced sonographers,’ but provided little detail as to the actual level of training of these providers. This makes it difficult to accurately assess the role that training may have in the detection of structural congenital anomalies.

#### Morbidity and mortality outcomes

Only four studies produced any data comparing the morbidity and mortality outcomes between neonates with an antenatal diagnosis versus neonates with a postnatal diagnosis (Table 4). In the study that addressed gastroschisis, outcomes were more favourable for neonates who had received an antenatal diagnosis compared with those who had not (20% vs 66.7% mortality). This was not the case for the study which addressed congenital anomalies.

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**Table 3 Training of personnel performing ultrasound examination**

| Author(s)               | Study location | # of anomalies detected (%) | Information about training of personnel performing antenatal ultrasound examinations |
|-------------------------|----------------|-----------------------------|------------------------------------------------------------------------------------|
| **Africa**              |                |                             |                                                                                     |
| Adeleye et al          | Nigeria        | 6/43 (14)                   | Radiologists performed 5% of cases; medical doctors performed 11%; unknown training/status performed 84% of cases |
| Adeleye and Joel-Medewase | Nigeria        | 26/146 (17.8)              | 22% of ultrasounds performed by a radiologist; sonographers in rest of the cases were personnel with unknown training; authors noted that prenatal diagnosis was significantly more likely in cases where sonographer was certified radiologist |
| Akinmoladun et al       | Nigeria        | 15/16 (93.8)                | A consultant radiologist trained in fetal anomaly scanning performed all the scans (the authors note that this radiologist received extensive training at a renowned centre in the UK) |
| Idowu and Olawehinmi    | Nigeria        | 23/91 (25.3)                | Authors noted that low diagnosis ‘may be due to the high prevalence of the test being done by non-specialist (untrained radiologist) in our environment’ |
| Wesonga et al           | Uganda         | 1/41 (2.4)                  | Performed by ultrasound technicians holding a diploma; no further information about diploma |
| **Asia**                |                |                             |                                                                                     |
| Liao et al             | China          | 28/36 (77.8)                | Ten certified physicians participated in the study protocol, each of whom has more than 5 years of experience in fetal sonography |
| Xie et al              | China          | Not specified               | 2 sonographers—1 with 10 years of experience in obstetric sonography and the other with 22 years of experience |
| Sanghvi et al          | India          | 65/125 (52)                 | Performed by ‘experienced sonologists’ |
| Ghavami and Abedinzadeh | Iran           | Not specified               | Performed by ‘two expert operators’ |
| Pitukkijronnakorn et al | Thailand       | 144/316 (45.6)              | All scans were performed by an obstetrician who was trained as a level one ultrasonography; in cases of uncertain abnormal findings, the women were reviewed by a level two obstetrician with repeated scans |
| **Europe**             |                |                             |                                                                                     |
| Iliescu et al          | Romania        | 74/76 (97.4)                | Scans performed by obstetricians specialising in prenatal diagnosis (including the anomaly scan and echocardiography) who had held accreditation for the 11–14 weeks assessment for at least 5 years prior to the start of the study period |
| Dane et al             | Turkey         | 23/24 (95.8)                | 2 operators with approximately 6 years and 2 years of experience in gestational ultrasound scanning |
| Kutuk et al            | Turkey         | Not specified               | All ultrasound scans performed by ‘two experienced maternal-fetal specialists’ |
| Oztekin et al          | Turkey         | 19/21 (90.5)                | All scans performed by the same experienced radiologist |
| **North America**      |                |                             |                                                                                     |
| Johnson et al          | Jamaica        | 44/57 (77.2)                | 8 OB/GYN residents in training for at least 2 years |
diaphragmatic hernia (CDH); however, this may reflect that more severe forms of anomalies are easier to detect antenatally.

**Termination rates**

Twenty-five studies (21 retrospective and 3 prospective observational studies and an ethnographic study) in 15 countries provided data on termination rates (table 5). Termination rates were highly varied, with a median of 17.1% in Africa, 34.4% in Asia, 50.2% in Europe and 62.4% in South America (range 0%–98.3%). Only one study from Africa evaluated termination rates for lethal anomalies and had just five participants. Thus, it is difficult to compare the termination rate of lethal anomalies with other regions, which contain such data. Termination rates can also be affected by the type of anomaly, the severity, the gestational age at diagnosis, the national termination policies and the cultural appropriateness of termination. Hence, while these termination rates offer valuable insight, it is necessary to also consider the underlying determinants that have impacted termination decisions.

**Referral rates for further antenatal care and management planning**

No studies addressed this issue.

**Policy data**

Thirteen articles provided policy data from 10 countries (table 6). Only two studies, in India and Brazil, mentioned national policies for antenatal ultrasound simply stating that they did not exist. Termination of pregnancy remains a highly sensitive topic in many communities, which is reflected in the variation of policies across the globe.

**Policy assessment**

WHO guidelines recommend the need for one antenatal ultrasound scan prior to 24 weeks gestation.13 Studies suggest that the ideal detection window for structural congenital anomalies is 19–21 weeks of gestation.14 At this point, it is possible to detect most structural congenital anomalies and is within the legal termination timeframe for many countries. Of note, many of the congenital anomalies detected antenatally in this review were not diagnosed until after 24 weeks gestation. This may be explained by the timing of the first antenatal ultrasound and/or the level of ultrasonographer training. The WHO recommends that ultrasound trainees receive at least 3–6 months of training, culminating in 300–500 ultrasound examinations.15 A recent study found that the majority of ultrasound providers in LMICs do not have the minimum training as set by the WHO.16 Hence, many ultrasound practitioners in LMICs may not have the skills to accurately detect congenital anomalies.

**DISCUSSION**

The median proportion of women receiving an antenatal ultrasound varied from 50.0% in Africa to 90.7% in Asia. It is likely that these are an overestimate of the true population rates considering that the majority of studies were undertaken at tertiary facilities. To fully understand what percentage of women receive antenatal ultrasound, further studies must be conducted at a population level, regionally and nationally, rather than at an institutional level. Research must also address the availability and accessibility of antenatal ultrasound and the barriers to receiving a scan.

Detection rates varied widely, from 0% to 100%, with the lowest reported rates in Africa (16.7%). Low detection rates may be because ultrasound providers did not
| Author(s) | Study location | Study type | Study population | # of fetuses | # of fetuses terminated (%) |
|-----------|----------------|------------|------------------|--------------|-----------------------------|
| **Africa** | | | | | |
| de Paul Djientcheu et al<sup>15</sup> | Cameroon | Retrospective descriptive observational study | Institutional; patients with NTDs | 8 | 0 (0%) |
| Shalaby et al<sup>95</sup> | Egypt | Retrospective cross-sectional study | Institutional; patients with urinary anomalies | 41 | 11 (26.8%) |
| Sorri and Mesfin<sup>43</sup> | Ethiopia | Retrospective cross-sectional study | Multi-centre; patients with NTDs at two tertiary hospitals | 177 | 13 (7.3%) |
| Akinmoladun et al<sup>44</sup> | Nigeria | Prospective descriptive observational study | Institutional; patients with lethal congenital anomalies | 5 | 4 (80%) |
| **Total** | 4 studies, 4 countries | 3 retrospective, 1 prospective observational studies | 3 institutional, 1 multicentre | 231 | 28 |
| Asia | | | | | |
| Li et al<sup>96</sup> | China | Retrospective descriptive observational survey | Regional; patients with NTDs | 160 | 72 (45%) |
| Lu et al<sup>93</sup> | China | Retrospective cross-sectional study | National (data from 20 counties); patients with NTDs | 361 | 355 (98.3%) |
| Xie et al<sup>91</sup> | China | Retrospective descriptive observational study | Institutional; patients with bronchopulmonary sequestration | 22 | 8 (36.4%) |
| Zhang et al<sup>87</sup> | China | Retrospective descriptive observational study | Institutional; patients with pulmonary sequestration | 68 | 2 (2.9%) |
| Kashyap et al<sup>98</sup> | India | Retrospective descriptive observational study | Institutional; patients with lethal congenital anomalies detected prior to 20 weeks of gestation | 103 | 80 (77.7%) |
| Kumar et al<sup>99</sup> | India | Prospective cohort study | Institutional; patients with severe renal anomalies | 55 | 9 (16.4%) |
| Kumar et al<sup>100</sup> | India | Prospective descriptive observational study | Institutional; patients with renal anomalies | 136 | 12 (8.8%) |
| Sanghvi et al<sup>96</sup> | India | Prospective descriptive observational study | Institutional; patients with lethal renal anomalies | 7 | 2 (28.6%) |
| Samadirad et al<sup>99</sup> | Iran | Retrospective descriptive observational study | Regional; patients with congenital anomalies | 603 | 201 (33.3%) |
| Munim et al<sup>63</sup> | Pakistan | Retrospective cohort study | Institutional; patients with congenital anomalies | 41 | 6 (14.6%) |
| Hsieh et al<sup>151</sup> | Taiwan | Retrospective descriptive observational study | Institutional; patients with diaphragmatic hernia | 31 | 11 (35.5%) |
| Jaruratanasirikul et al<sup>102</sup> | Thailand | Retrospective cross-sectional study | Regional; patients with NTDs | 28 | 12 (42.9%) |
| Pitukkijronnakorn et al<sup>64</sup> | Thailand | Prospective cross-sectional study | Institutional; patients with congenital anomalies | 316 | 87 (27.5%) |
| Gammeltoft et al<sup>103</sup> | Vietnam | Ethnographic study | Institutional; patients with congenital anomalies | 30 | 17 (56.7%) |
| **Total** | 14 studies, 7 countries | 9 retrospective, 4 prospective observational studies; 1 ethnographic study | 10 institutional, 3 regional, 1 national | 1961 | 874 |
| **Europe** | | | | | |
| Tudorache et al<sup>71</sup> | Romania | Retrospective descriptive observational study | Institutional; patients with severe CDH diagnosed in the second trimester of pregnancy | 6 | 4 (66.7%) |

Continued
specifically screen for congenital anomalies. Currently, many women in LMICs receive antenatal ultrasound examinations for the assessment of pregnancy progress, such as to determine the gestational age, sex of the baby and to hear the heartbeat, rather than to detect anomalies. This is in contrast to HICs where the majority of women receive an anomaly scan around 20 weeks gestation.\textsuperscript{14} Another possible reason for low detection may be the training level of the ultrasound provider; there appears to be a trend between higher levels of training and higher detection rates. This warrants further investigation to determine minimum training requirements and associated policy and monitoring.

The First Look Study is an important randomised controlled trial which assessed the use of antenatal ultrasound in the Democratic Republic of the Congo, Guatemala, Kenya, Pakistan and Zambia.\textsuperscript{17} Although 95\% of women in their intervention group received antenatal ultrasound scans (compared with 43\% in the control group) and detection rates improved, hospital delivery did not increase for complicated pregnancies and thus there was no resultant improvement in neonatal mortality. In an additional survey by the same group, barriers to referral attendance included cost, distance and lack of transportation.\textsuperscript{18} For women who did attend referral, barriers included not being connected to the correct provider and being told to return at a later time.\textsuperscript{18} The authors conclude that without improvement of subsequent care, antenatal ultrasound offered limited impact.\textsuperscript{17} Hence, to reduce neonatal morbidity and mortality, detection of an anomaly must be followed by referral for antenatal counselling and delivery at a tertiary centre which can provide the necessary surgical care at birth where required. It is also necessary to offer termination for conditions which are incompatible with life, where culturally acceptable.

Hence, it is vital to further investigate barriers to accessing delivery at a paediatric surgery centre once a congenital anomaly has been diagnosed and ways to address these barriers. Future studies must also investigate the effects of both antenatal diagnosis and delivery at a tertiary paediatric surgery centre on morbidity and mortality outcomes in the LMIC setting; this systematic review highlighted a severe lack of such vital data. The recently completed Global Paedsurg study may provide such data for a selection of common gastrointestinal congenital anomalies globally, which collectively have a particularly high mortality in the LMIC setting.\textsuperscript{19} As anomaly screening rates increase in LMICs, it will be also be important to monitor termination rates along with reasons for termination, to ensure the benefits of antenatal diagnosis are optimised both clinically and ethically.

To address some of these issues, there is a need for global collaboration. This collaboration must include members from multidisciplinary backgrounds, including

| Author(s) | Study location | Study type | Study population | # of fetuses | # of fetuses terminated (%) |
|-----------|----------------|------------|------------------|--------------|-----------------------------|
| Aygun et al\textsuperscript{23} | Turkey | Retrospective descriptive observational study | Institutional; patients with NTDs | 72 | 0 (0\%) |
| Oztarhan et al\textsuperscript{24} | Turkey | Retrospective cohort study | Institutional; patients with lethal congenital anomalies | 1906 | 640 (33.6\%) |
| Sahinoglu et al\textsuperscript{27} | Turkey | Retrospective case series (6 cases) | Institutional; patients with body wall complex | 6 | 4 (66.7\%) |
| Total | 4 studies, 2 countries | 4 retrospective observational studies | 4 institutional | 1990 | 648 |
| North America | | | | | |
| Johnson et al\textsuperscript{42} | Jamaica | Retrospective descriptive observational study | Institutional; patients with congenital anomalies | 44 | 10 (22.7\%) |
| Total | 1 study, 1 country | 1 retrospective observational study | 1 institutional | 44 | 10 |
| South America | | | | | |
| Brizot et al\textsuperscript{106} | Brazil | Retrospective descriptive observational study | Institutional; pairs of conjoined twins in which surgical separation was impossible and the condition lethal | 36 | 30 (83.3\%) |
| Pelizzari et al\textsuperscript{106} | Brazil | Retrospective cohort study | Institutional; patients with anencephaly | 29 | 12 (41.4\%) |
| Total | 2 studies, 1 country | 2 retrospective observational studies | 2 institutional | 65 | 42 (64.6\%) |

CDH, congenital diaphragmatic hernia; NTD, neural tube defects.
Table 6  Policy data

| Author(s)                          | Study location | Policy data about antenatal screening and/or termination legislation                                                                                                                                                                                                 |
|-----------------------------------|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| **Africa**                        |                |                                                                                                                                                                                                                                                                                                                                 |
| Oloyede and Oyedele<sup>107</sup> | Nigeria        | In Nigeria, the two existing pregnancy termination laws are restrictive in nature. However, termination is often done when a fetus is malformed on the grounds of preserving the mental health of the women.                                                                               |
| **Asia**                          |                |                                                                                                                                                                                                                                                                                                                                 |
| Acharya et al<sup>108</sup>       | India          | India has no definite policy for the ultrasound screening for fetal abnormalities and antenatal diagnostic techniques. The law in India says that those who meet the criteria of the PCPNDT Act can perform an ultrasound scan and they must be sufficiently trained and registered with the proper authority.        |
| Neogi<sup>109</sup>               | India          | Abortion was legalised in India in 1971 under the Medical Termination of Pregnancy Act. It permits abortion by 1 doctor before 12 weeks of gestation but if the duration of pregnancy is more than 12 weeks but less than 20 weeks, then the opinion of 2 medical practitioners is necessary to terminate the pregnancy. |
| Phadke et al<sup>110</sup>        | India          | In India, the Medical Termination of Pregnancy Act of 1971 (The MTP Act, No. 34 of 1971) does not allow pregnancy termination on grounds of fetal abnormality after 20 weeks of gestation.                                                                                   |
| Ranji and Dykes<sup>111</sup>     | Iran           | According to the regulations of the Iranian Ministry of Health, ultrasound examinations during pregnancy must be carried out by radiologists.                                                                                                                             |
| Arawi and Nassar<sup>112</sup>    | Lebanon        | Lebanese law stipulates that pregnancy termination is forbidden except when the pregnancy endangers the health of the mother and only after consulting with two physicians.                                                                                                         |
| Senanayake and de Silva<sup>113</sup> | Sri Lanka   | In Sri Lanka, it is illegal to terminate a pregnancy even in cases of early diagnosis (11–14 weeks of gestation).                                                                                                                                                          |
| **Europe**                        |                |                                                                                                                                                                                                                                                                                                                                 |
| Hostiuc et al<sup>114</sup>       | Romania        | According to Romanian law, abortion over 14 weeks is only allowed in cases of severe congenital defects and pregnancies that threaten the life of the mother.                                                                                                                     |
| Oztarhan et al<sup>104</sup>      | Turkey         | Turkish law authorises pregnancy termination voluntarily until 10 weeks in unwanted pregnancies and at any gestational age for medical indications that are considered potentially life threatening to the mother or fetus. The legal process requires one obstetrician and one physician to agree that pregnancy termination is valid for a medical reason. |
| **North America**                 |                |                                                                                                                                                                                                                                                                                                                                 |
| Lisker et al<sup>115</sup>        | Mexico         | Pregnancy termination is illegal in most Mexican States, except in the case of rape or if the mother’s life is at risk by the continuation of pregnancy. In Mexico City and 12 of the 31 states, the presence of a severe congenital anomalies has become a justification for the legal termination of pregnancy. |
| **South America**                 |                |                                                                                                                                                                                                                                                                                                                                 |
| Groisman et al<sup>116</sup>      | Argentina      | According to the Argentinian criminal code, termination of pregnancy is illegal unless the pregnancy is threat to woman’s life or pregnancy is consequence of rape of a mentally retarded woman. In the city of Buenos Aires, it is legal to induce labour after 24 weeks of gestational age in case of anencephaly and other lethal conditions. |
| Benute et al<sup>117</sup>        | Brazil         | Brazilian law does not include lethal fetal malformation as an indication for pregnancy termination; however, many couples ask a court for permission to terminate a pregnancy on the grounds that it is the option which creates less suffering.                                                       |
| Mirlesse and Ville<sup>118</sup>  | Brazil         | Ultrasound is not explicitly recommended by Brazilian authorities. Brazilian legislation considers termination of pregnancy to be a crime (except in cases of rape or pregnancies which risk the mother’s life). However, for lethal fetal malformations, it is possible to apply to the courts for an exceptional authorisation to abort. These requests require a medical referral centre to perform an ultrasound and prepare a very detailed file. |

PCPNDT, Pre-Conception and Pre-Natal Diagnostic Techniques Act.
policymakers, obstetricians, neonatologists, paediatric surgeons, midwives and allied professionals. The Global Initiative for Children’s Surgery (GICS) is a multidisciplinary collaborative whose aim is to improve health outcomes for children requiring surgery in LMICs. This initiative connects the expertise of providers in LMICs and HICs and is committed to expanding the representation and leadership of stakeholders in LMICs. GICS has recently created a congenital anomalies working group, which is planning some of the following projects: (1) to produce guidelines on how to diagnose structural congenital anomalies via antenatal ultrasound; (2) to produce referral and management guidelines following an antenatal diagnosis; and (3) to produce information sheets that can be translated into various languages for parents that contain details about common congenital anomalies. Global collaboration must also extend to the level of the WHO and the Ministries of Health to ensure that recommendations are detailed in policy and implemented into practice.

If these steps are taken, improvements in neonatal health outcomes may be realised, as seen in HICs. Early detection and immediate surgical intervention of congenital anomalies, such as gastrochisis, has been effective in significantly reducing neonatal mortality in HICs. The mortality of gastrochisis has significantly improved in HICs over a period of 50 years, to less than 5% today. This can be attributed to improvements in accurately diagnosing gastrochisis antenatally, monitoring the fetus for complications, and planning for delivery at a facility with paediatric surgeons available. Similar trends have been seen for other congenital anomalies in HICs such as intestinal atresia, CDH, omphalocele, oesophageal atresia and posterior urethral valves. By understanding the current role of antenatal ultrasound in LMICs and the barriers to detection, referral and management of structural congenital anomalies, appropriate interventions can be implemented to help improve outcomes.

Although this systematic review provides useful data, it is also important to note a few of the limitations of the study. First, only articles in English were included in this systematic review, which may exclude other relevant studies. This study used four electronic databases for the search. The expansion of search databases to include African Journals Online, Scielo and Regional WHO’s African Index Medicus may have provided other studies from LMICs that were not indexed in the search engines used. It is vital to include these databases in future research focusing on LMICs. Furthermore, it is important to note that antenatal ultrasound has further diagnostic capabilities, such as detecting abnormal growth or improper placental position and this review only focused on the detection of structural congenital anomalies. Further studies could also include other uses of antenatal ultrasound for improving neonatal and indeed maternal health outcomes. Finally, the policy data in this study represent what was accurate when the studies were published. Some of the policy data may now be out of date.

**CONCLUSION**

The data from this review suggest that the percentage of women in LMICs who receive an antenatal ultrasound examination varies considerably and is particularly low in sub-Saharan African countries. Even when antenatal ultrasound scans are performed, accurate detection rates are often very low. The level of training (and the type of training) of the sonographer may be indicative of the accuracy of diagnosis. Only four studies delineated the morbidity and mortality outcomes among neonates with an antenatal diagnosis compared with postnatal diagnosis. Hence, although the benefits of antenatal ultrasound are widely demonstrated in HICs, data are severely lacking in LMICs. It is clear that the use of antenatal ultrasound in LMICs is not maximised to its highest potential.

### What is known about the subject?

- Congenital anomalies are the fifth leading cause of death in children under 5 years of age globally.
- Ninety-seven per cent of congenital anomaly deaths occur in low/middle-income countries (LMICs), many of which may be preventable with antenatal diagnosis and planned surgical intervention following birth.
- Antenatal ultrasound examinations in HICs are commonplace and highly accurate, but accessibility and effectiveness are limited in LMICs.

### What this study adds?

- Rates of antenatal ultrasound examination vary significantly in LMICs, ranging from 6.8% to 98.8%.
- There is significant variation in the accuracy of antenatal diagnosis in LMICs, with detection rates varying from 0% to 100% (median of 16.7% in Africa).
- Available data suggest that the level of ultrasonographer training may affect the accuracy of diagnosis, but further research into this is required.

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### Contributors

NW conceived the idea for this study. NW, AK and SMG devised the study design. SMG, SS-B, NA-A, LIN, MTB and NW performed the literature review. SMG drafted the manuscript with significant contributions from NW and AK. All authors reviewed and approved the final submitted manuscript.

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