

# Cranial ultrasound in neonates and infants in rural Africa

Carsten Krüger, MD, FRCPCH (UK), MIH

Haydom Lutheran Hospital, PO Mbulu, Tanzania, and Department of Paediatrics, St Franziskus Hospital, Ahlen, Germany

Naftali Naman, AMO

Assistant Medical Officer Diagnostic Radiology, Haydom Lutheran Hospital

Corresponding author: C Krüger (thea.carsten.krueger@web.de)

**Objective.** To evaluate the usefulness of cranial ultrasound (CU) at a rural hospital in a developing country setting and to analyse how indications, results and therapeutic consequences differ from those in developed countries.

**Methods.** All CU scans performed over a 32-month period at Haydom Lutheran Hospital, Tanzania, were retrospectively analysed. The patients' presenting signs and symptoms were categorised into nine groups: 1. birth asphyxia; 2. congenital syndromes; 3. neural tube defects/spina bifida; 4. macrocephalus; 5. post-meningitis; 6. seizures; 7. developmental/neuromuscular abnormalities; 8. head trauma; and 9. miscellaneous. The information derived from the scans was then analysed with regard to underlying pathology and possible influence on the child's future management.

**Results.** 420 scans were performed in 293 patients, of whom 34 were older than 1 year. In 155 cases no abnormal result was obtained. When results of the abnormal scans were related to their impact on patient management, the pathological findings were found to have provided useful information in groups 1 (45%), 3 (100%), 4 (87%), 6 (57%), 6 (31%) and 7 (45%).

**Conclusions.** CU is a highly feasible technique even in resource-poor settings and provides valuable additional information in patients with neural tube defects/spina bifida, macrocephalus, post-meningitis, birth asphyxia, developmental/neuromuscular abnormalities and seizures.

In industrialised countries CU plays a significant role in the diagnostic approach to intracranial disorders in neonatology (and to a minor degree in paediatrics) and influences therapeutic decisions to quite a large degree.<sup>1,2</sup> Major indications for CU are prematurity because of risk of intracerebral haemorrhage, birth asphyxia, suspected intracranial malformations, infections, trauma and metabolic disease.<sup>1,2</sup> Its advantages are ease of application, availability for frequent, serial exams at the bedside with minimal disturbance of the neonate or infant, freedom from negative side-effects and radiation exposure, low cost, and its potential as a screening tool.<sup>1,2</sup> Technically, the application of CU is mainly confined to the infant period until the fontanelle closes.<sup>1,2</sup> The majority of examinations are therefore performed during the neonatal period and early infancy. Sometimes, depending on the quality of the ultrasound device and the transducers, it is possible to scan through the sutures at a later age.

Although no one would question the value of CU in affluent health systems, surprisingly little information is provided on its usefulness in a developing country setting. There are a few published studies from Asia and Africa, but these were usually performed at tertiary institutions.<sup>3-17</sup> We therefore decided to retrospectively analyse our data on CU scans performed at a remote rural hospital in Tanzania on several hundred patients. We were interested in exploring its usefulness in this resource-poor setting, especially as no other cerebral imaging, such as computed tomography (CT) or magnetic resonance imaging (MRI), was available at the time of the study, and in comparing

indications, results and possible therapeutic consequences with those in industrialised countries.

## Methods

### Setting

The study was performed at Haydom Lutheran Hospital (HLH), a rural hospital in northern Tanzania, owned by the Mbulu diocese of the Evangelical Lutheran Church in Tanzania. The hospital is located at the southern edge of Mbulu district, which is at the south-western border of the Manyara region (380 km south-west of Mount Kilimanjaro).<sup>18-22</sup> People in the area mainly live by means of subsistence farming and livestock keeping. The hospital officially contains 400 beds and serves a population of more than 500 000 people. It has surgical, internal medicine, gynaecological/obstetric, paediatric and tuberculosis wards.<sup>18-22</sup> Each year more than 12 000 inpatients and 70 000 outpatients are treated. Children represent about 30 - 40% of total patient numbers.<sup>18-22</sup> Each year about 3 500 - 4 000 children are born at the hospital, but more than 12 000 are born at home without skilled attendance in the total catchment area.<sup>18-22</sup> The prematurity rate is about 10%, but very premature infants, born before 32 weeks' gestation, rarely survive the first day of life. At the time of the study, more than 25 000 examinations in pregnant women and more than 65 000 in children aged under 5 years were performed in 22 mobile maternal and child health (MCH) clinics, located up to 100 km away from HLH and served on a monthly basis, and one permanent MCH clinic at HLH.<sup>18-22</sup>

At the radiology department, which was led by the co-author (NN), an assistant medical officer trained in diagnostic radiology, only routine radiography, including contrast studies, was available at the time of the study. Plain skull X-rays are not suitable to detect intracranial pathology, and neither CT nor MRI was available. The closest medical facility with CT was located more than 350 km from the hospital. A small portable ultrasound device (Aloka Echo Camera SSD 500, Aloka, Tokyo, Japan) had been donated to the hospital and was used for all indications and age groups. The only probe of several we had that was to some degree appropriate for CU was a 3.5 MHz curved array transducer, without any Doppler or colour Doppler technique, which was not ideal for neonates and infants. Equipment for print or electronic documentation of results was not available. For a catchment area with a radius of at least 250 km, the hospital provided the only opportunity for CU.

All scans were performed by the two authors. Each examination lasted about 5 - 10 minutes and included at least three coronal views, one midline sagittal view, and one parasagittal view on each side. After infancy, scans were performed through sutures which were still widened in these patients to a varying degree. CK had trained NN in this technique and acted as a supervisor.

**Patients**

Data on all in- and outpatients in whom CU was performed during diagnostic evaluation over a 32-month period were retrospectively collected from the records of the radiology department. Age (in months) at the time of examination, gender, indication, results and number of repeat exams, if done, were recorded.

According to history and presenting signs and symptoms, the patients were then categorised into nine groups which represented the indications for the ultrasound exams: 1. birth asphyxia; 2. congenital syndromes; 3. neural tube defects/spina bifida; 4. macrocephalus; 5. post-meningitis; 6. seizures; 7. developmental/neuromuscular abnormalities; 8. head trauma; and 9. miscellaneous (infections, septicaemia, HIV, malnutrition, rickets, shock, prematurity, etc.). Within these categories, the results of the scans were listed and compared with the other categories in terms of frequency and type of pathology. The information derived from the scans was then analysed with regard to the child's future management (no specific treatment, pharmacological, surgery, prognostic value).

**Statistics**

All data were entered manually in data collection sheets, checked for inconsistencies and then entered into SPSS v15.0 for analysis. Random checks were conducted to minimise errors from data entry. Differences in frequencies within and between the patient groups and categories were analysed using the chi-square test. The level of significance (two-sided) was defined as  $p < 0.05$ .

**Ethical approval**

This work is based on the authors' clinical work at Haydom Lutheran Hospital. Permission for publication was granted by the then medical director, the late Dr O H E Olsen.

**Results**

We performed 420 scans in 293 patients (162 males and 131 females;  $p=0.07$ ). Of these, 34 were older than 1 year, the 3 oldest being 7, 9 and 15 years old (Fig. 1). In 155 patients (166 scans performed), no abnormal results were obtained; 20 of these patients were older than 1 year. In the remaining 138 patients (14 older than 1 year) 254 scans were performed in total, all with abnormal results (Table I, Fig. 1). Patient numbers in the different categories were as follows: birth asphyxia 31; congenital syndromes 16; neural tube defects/spina bifida 14; macrocephalus 38; post-meningitis 79; seizures

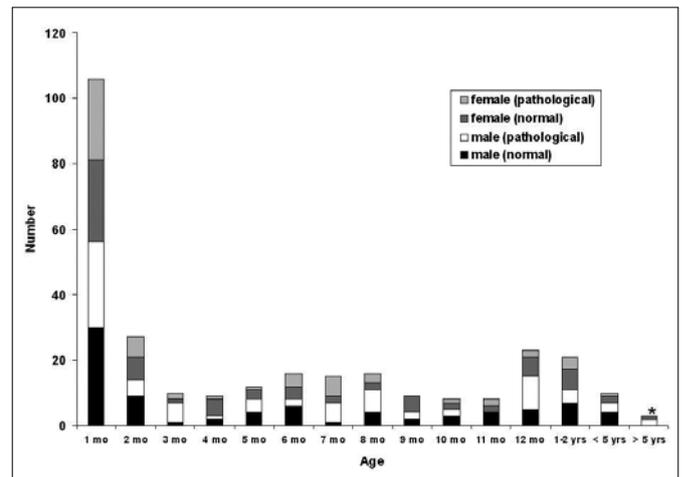


Fig. 1. Patient age, gender distribution and numbers with pathological findings (\* = 7, 9 and 15 years old).

TABLE I. PATIENT NUMBERS AND SCANS ACCORDING TO RESULTS AND INDICATION GROUPS

Indication group	Pathological results (N (patients >1 year))		Normal results (N (patients >1 year))		Pathological findings	
	Patients	Scans	Patients	Scans	%	p-value*
Birth asphyxia	14 (0)	16	17 (0)	21	45	>0.05
Congenital syndromes	2 (0)	2	14 (1)	14	13	<0.05
Spina bifida	14 (1)	32	0 (0)	0	100	<0.05
Macrocephalus	33 (5)	78	5 (0)	6	87	<0.05
Post meningitis	45 (4)	85	34 (6)	36	57	>0.05
Seizures	4 (1)	8	9 (1)	9	31	>0.05
Developmental/neuromuscular abnormalities	20 (3)	25	24 (4)	26	45	>0.05
Head trauma	1 (0)	2	16 (3)	16	6	<0.05
Miscellaneous	5 (0)	6	36 (5)	38	12	<0.05
Total	138 (14)	254	155 (20)	166	47	

\*Chi-square test.

13; developmental/neuromuscular abnormalities 44; head trauma 17; and miscellaneous 41 (Table I). Patients older than 1 year were represented in all groups except the birth asphyxia group, although they were usually few in numbers.

Abnormal findings in the different categories were as follows: birth asphyxia 45% (abnormal/total 14/31); congenital syndromes 13% (2/16); neural tube defects/spina bifida 100% (14/14); macrocephalus 87% (33/38); post-meningitis 57% (45/79); seizures 31% (4/13); developmental/neuromuscular abnormalities 45% (20/44); head trauma 6% (1/17); and miscellaneous 12% (5/41) (Table I). Among the older patients, only in the groups with neural tube defects/spina bifida, macrocephalus, post-meningitis, seizures and developmental/neuromuscular abnormalities did some scans show important pathological findings.

When analysing the type of abnormality within the different categories (Table II), the most common finding was hydrocephalus, mainly in the macrocephalus and post-meningitis groups. All patients with spina bifida had the Arnold Chiari type II malformation (associated with hydrocephalus), and brain oedema in the asphyxia group was the third most common abnormality. All other abnormalities were much less frequent, especially intracranial haemorrhage. Very few premature infants in this setting survived the first days of life, so CU was only performed in 2 of them.

When relating the results of the scans to their possible impact on patient management, the impact on treatment was largest in patients with neural tube defects/spina bifida, macrocephalus and post-meningitis; 21 of these patients were operated on and received a ventriculo-peritoneal shunt for drainage, employing a simple feeding tube as the shunt device.<sup>23</sup> In the birth asphyxia, seizures and developmental/neuromuscular groups, abnormalities were found in almost half of the patients but because therapeutic options were limited no specific treatment beyond standard care, such as anticonvulsant

medication or physiotherapy, could be offered. In these cases the ultrasound results sometimes guided prognostic advice. In the three remaining groups the diagnostic yield was very low (Tables I and II).

## Discussion

The value of diagnostic ultrasound in developing country settings has already been evaluated thoroughly.<sup>24</sup> Several years ago the World Health Organization recommended its use in low-resource settings.<sup>25-27</sup> All reports favour its application and consider it a cost-effective diagnostic method in fields as diverse as internal medicine, surgery and gynaecology and obstetrics.<sup>24-26</sup> Especially in obstetric care in developing countries it is highly valued and judged indispensable in the management of pregnant women and during labour.<sup>28-30</sup> In paediatrics several reports on ultrasound in general support the utility of this diagnostic method in these countries.<sup>30-32</sup>

Surprisingly, only a few studies of CU have been conducted in a developing country setting so far, usually focusing on one or two indications such as intraventricular haemorrhage or hydrocephalus in neonates. Reports have come from India,<sup>34</sup> Turkey,<sup>12,13</sup> South Korea,<sup>14</sup> Cameroon,<sup>5</sup> Ivory Coast,<sup>6</sup> Malawi,<sup>8</sup> Nigeria,<sup>7,9-11</sup> Uganda,<sup>15</sup> Taiwan<sup>16</sup> and Malaysia.<sup>17</sup> As indicated earlier, these studies were mainly performed at tertiary institutions with appropriate technology and standard therapeutic opportunities, rather than in remote, rural health institutions with scarce resources. In the studies from India,<sup>3</sup> Nigeria,<sup>10,11</sup> Turkey<sup>12,13</sup> and South Korea,<sup>14</sup> premature infants and their risk of intraventricular haemorrhage were assessed. As expected, the findings were similar to those in industrialised countries,<sup>1</sup> with a higher risk of intraventricular haemorrhage in very premature infants. Our own findings with regard to premature infants will be discussed below.

In one recent study from Uganda, well newborn infants were examined with sophisticated equipment, and almost 50% showed some minor abnormalities at CU.<sup>15</sup> The authors

TABLE II. INDICATION GROUPS AND TYPE OF PATHOLOGY

Type of pathology (finding/patient)*	Indication group								
	Birth asphyxia	Congenital syndromes	Spina bifida	Macrocephalus	Post meningitis	Seizures	Developmental/neuromuscular abnormalities	Head trauma	Miscellaneous
(finding/patient)*	14/14	2/2	14/14	37/33	47/45	6/4	20/20	1/1	5/5
Arnold Chiari II†	-	-	14	-	-	-	-	-	-
Hydranencephaly	-	-	-	3	-	-	1	-	-
Holoprosencephaly	-	-	-	3	-	-	-	-	-
Other malformations	-	-	-	6	-	-	-	-	-
Hydrocephalus	1	-	-	22	38	2	4	-	4
Ventriculitis	-	-	-	-	6	-	-	-	-
Abscess	-	-	-	-	1	2	1	-	-
Cysts	-	1	-	1	1	-	1	-	-
Haemorrhage	1	-	-	-	-	1	2	1	1
Calcifications	-	1	-	-	1	-	5	-	-
Oedema	12	-	-	-	-	-	-	-	-
Brain atrophy	-	-	-	-	-	1	6	-	-
Subdural effusions	-	-	-	2	-	-	-	-	-

\*More than one pathological finding per patient possible.  
†Associated with hydrocephalus.



**Nowadays  
ultrasound devices  
can be used even  
without a permanent  
electricity supply,  
as many function on  
rechargeable  
batteries.**

postulated that this high percentage of abnormal findings in otherwise healthy neonates might be related to a high rate of congenital infections. Two other studies from Taiwan and Malaysia produced similar results.<sup>16,17</sup> Limited resources prohibited routine CU in apparently healthy neonates in the current study.

Other studies from India,<sup>4</sup> Cameroon,<sup>5</sup> Ivory Coast,<sup>6</sup> Nigeria<sup>7</sup> and Malawi<sup>8</sup> assessed the value of CU in the diagnostic management of children with meningitis, who often present with hydrocephalus. Up to 50% of infants and children developed complications such as hydrocephalus after meningitis in these studies, which is in line with our results in this indication group (Tables I and II). Macrocephalus of non-infectious origin (congenital hydrocephalus, other malformations) was studied in other reports from Nigeria<sup>7,9</sup> and Malawi.<sup>8</sup> Similar to our results, in up to 60% of patients a diagnosis could be made by CU. In Malawi<sup>8</sup> the study population included children with spina bifida, all presenting with hydrocephalus, as was seen in our patients.

All the studies affirmed the ease and value of performing CU in developing countries, especially with regard to early detection of complications in meningitis, the diagnostic approach in hydrocephalus and macrocephalus, and possible therapeutic interventions in hydrocephalus. The studies from India and Africa demonstrated that complications after meningitis constitute a significant proportion of CU findings in these resource-limited settings, which parallels our results (Tables I and II).<sup>4-8</sup>

To the best of our knowledge, this report on CU in developing countries is the first from an institution outside a university setting. Our results show that CU can be recommended as a fast, easy-to-perform, feasible, practical, cost-effective and efficient technique in resource-poor settings. It provides valuable additional diagnostic information in patients with spina bifida and macrocephalus and after meningitis (Tables I and II), in a similar range as reported in the literature.<sup>4,9</sup> The post-meningitis group had the largest number of patients and scans, with more than 55% pathological results (Tables I and II), indicating the high risk of complications and the need for close sonographic follow-up.<sup>4-8</sup> The high rate of pathological results in patients with spina bifida and macrocephalus also serves as a clear indication for CU, especially because in all these patients, including post-meningitis, treatment options such as ventriculo-peritoneal shunting are available.<sup>7-9,23,33,34</sup> Ventriculo-peritoneal shunting in these settings carries a 10 - 20% risk of postoperative mortality and a 20 - 30% postoperative morbidity rate, but in many patients the overall prognosis can still be improved considerably.<sup>23,33,34</sup>

The diagnostic yield was lower for birth asphyxia in term neonates, developmental/neuromuscular abnormalities and seizures (Tables I and II). These indications for CU have not yet been part of a study in developing countries, except for birth asphyxia, where more than 70% abnormal findings were detected in a Malaysian study.<sup>17</sup> Our results indicate that it is reasonable to perform CU in these patients, even

though there may not be any treatment available other than options such as anticonvulsant therapy or physiotherapy. Its main value could then be to obtain additional information for prognosis and for counselling the patients and their families.

In the three remaining indication groups, the diagnostic and hence therapeutic or prognostic yield was very low. As only a few premature infants survived the first days of life, we performed CU in only 2 of them (one patient with intraventricular haemorrhage). This is in stark contrast to developed countries and tertiary institutions in developing countries, where this age group probably represents the most common indication.<sup>1,2,10-14</sup> Typically in developed countries the majority of scans are performed in very premature neonates of less than 32 weeks' gestation, who in developing countries rarely survive in non-specialised health institutions like our rural hospital. The more survival of very premature infants increases in resource-limited settings, the more this group will provide a major indication for CU. In one study from Nigeria, more pathological results were found in infants with congenital abnormalities.<sup>9</sup> This finding is probably explained by differences in patient characteristics in the two studies.

Nowadays ultrasound devices can be used even without a permanent electricity supply, as many function on rechargeable batteries. Some have specifically been developed to withstand the rough conditions (heat, humidity, dust, mechanical impact) in tropical and sub-tropical climates.<sup>30,35</sup> However, the quality of results in ultrasound also depends very much on the training and experience of the operator. Given that CU in particular has not been widely used in developing countries so far, the question arises whether it is possible to train physicians and non-physician health workers in this technique outside referral institutions. Our own experience is positive, as the first author (CK) trained his colleague (NN) to perform CU in a short time, and reliable results were obtained thereafter. At Weill Bugando University College of Health Sciences in Mwanza, Tanzania, ultrasound training including CU is part of postgraduate teaching during the 3-year curriculum leading to a Master in Medicine Paediatrics.<sup>36</sup> Other authors report on their favourable experiences while training midwives in obstetric ultrasound in Mauritania,<sup>37</sup> radiographers and assistant medical officers in general ultrasound in Pemba, Tanzania,<sup>38</sup> and physicians in CU in Uganda.<sup>15</sup> Taken together, these findings support the feasibility of CU in developing countries.

In conclusion, even with sub-optimal equipment, as was the case in our setting, valuable additional information could be obtained by CU. In older patients scans are possible when sutures are widened, but typically they are unreliable and should be replaced by CT or MRI when possible. For infants with an open fontanelle CU remains invaluable as a fast, easy-to-perform and useful bedside tool. We would therefore recommend its more frequent use in developing countries in the care of neonates and infants with a wide range of clinical presentations, particularly spina bifida, macrocephalus and post-meningitis.

This work is dedicated to the then medical director of Haydom Lutheran Hospital, the late Dr Ole Halgrim Evjen Olsen, who worked tirelessly for the health of the people of the Haydom area for several decades.

**Funding:** None.

**Conflicting interests:** The authors declare that they have no conflicting interests.

**Authors' contributions:** CK developed the idea and structure of the study. CK and NN performed the ultrasound examinations, collected, analysed and interpreted the data, and wrote the manuscript. Both authors read and approved the final manuscript.

## References

- van Wezel-Meijler G, Steggerda SJ, Leijser LM. Cranial ultrasonography in neonates: role and limitations. *Semin Perinatol* 2010;34:28-38.
- van Wezel-Meijler G. Neonatal Cranial Ultrasonography: Guidelines for the Procedure and Atlas of Normal Ultrasound Anatomy. 1st ed. Berlin: Springer, 2007: 1-162.
- Soni JP, Singhania RU, Sharma A. Measurement of ventricular size in term and preterm infants. *Indian Pediatr* 1992;29:55-59.
- Kapoor R, Saha MM, Gupta NC. Ultrasonic evaluation of complicated meningitis. *Indian Pediatr* 1989;26:804-808.
- Gonsu-Fotsin J, Kago I, Dzogang MT, Kamga HG, Camara M. Cerebral complications of purulent meningitis in children assessed by transfontanelar ultrasonography in Yaounde (Cameroon). *Ann Radiol (Paris)* 1990;33:195-199.
- Eholie SP, Boni N, Aoussi E, et al. Neurosurgical complications of purulent meningitis in the tropical zone [French]. *Neurochirurgie* 1999;45:219-224.
- Tabari AM, Isyaku K, Mamman M, Ma'aji S, Idris SK. Experience on transfontanelle neurosonography in Kano, Nigeria: a preliminary report. *Niger Postgrad Med J* 2008;15:255-258.
- Adeloye A, Khare R. Ultrasonographic study of children suspected of hydrocephalus at the Queen Elizabeth Central Hospital in Blantyre, Malawi. *East Afr Med J* 1997;74:267-270.
- Nzeh DA, Erinle SA, Saidu SA, PamSD. Transfontanelle ultrasonography: an invaluable tool in the assessment of the infant brain. *Trop Doct* 2004;34:226-227.
- Nzeh DA, Ajayi OA. Sonographic diagnosis of intracranial hemorrhage and periventricular leukomalacia in premature African neonates. *Eur J Radiol* 1997;26:77-82.
- Ajayi O, Nzeh DA. Intraventricular haemorrhage and periventricular leukomalacia in Nigerian infants of very low birth weight. *West Afr J Med* 2003;22:164-166.
- Ilikkan B, Vural M, Yardimci D, Ozbek S, Perk Y, Ilter O. Intraventricular hemorrhage in preterm newborns. *Turk J Pediatr* 1998;40:195-200.
- Vural M, Yilmaz I, Ilikkan B, Erginoz E, Perk Y. Intraventricular hemorrhage in preterm newborns: risk factors and results from a university hospital in Istanbul, 8 years after. *Pediatr Int* 2007;49:341-344.
- Lee JY, Kim HS, Jung E, et al. Risk factors for periventricular-intraventricular hemorrhage in premature infants. *J Korean Med Sci* 2010;25:418-424.
- Hagmann CF, Robertson NJ, Acolet D, et al. Cranial ultrasound findings in well newborn Ugandan infants. *Arch Dis Child Fetal Neonat Ed* 2010;95:F338-344.
- Wang LW, Huang CC, Yeh TF. Major brain lesions detected on sonographic screening of apparently normal term neonates. *Neuroradiology* 2004;46:368-373.
- Boo NY, Chandran V, Zulfiqar MA, et al. Early cranial ultrasound changes as predictors of outcome during first year of life in term infants with perinatal asphyxia. *J Paediatr Child Health* 2000;36:363-369.
- Hinderaker SG. Perinatal mortality and anaemia in pregnancy in rural northern Tanzania. Doctoral thesis, Centre for International Health, Faculty of Medicine, University of Bergen, 2003.
- Olsen BE. Motherhood - a hazardous endeavour. Maternal deaths and urinary tract infections in pregnancy in rural northern Tanzania. Doctoral thesis, Centre for International Health, Faculty of Medicine, University of Bergen, 2002.
- Evjen-Olsen B, Olsen OE, Kvale G. Achieving progress in maternal and neonatal health through integrated and comprehensive healthcare services - experiences from a programme in northern Tanzania. *Int J Equity Health* 2009;8:27.
- Maestad O, Brehony E. Review of Haydom Lutheran Hospital. CMI Report R2007:18. Bergen: Chr. Michelsen Institute, 2007: 1-44.
- Haydom Lutheran Hospital. Haydom Lutheran Hospital - Annual reports 1998-2008. Haydom: Haydom Lutheran Hospital, 1999-2009.
- Krüger C, Olsen OHE. Short-term outcome of infants with hydrocephalus in rural Tanzania after insertion of ventriculo-peritoneal shunts using simple feeding tube devices (abstract). *Monatsschr Kinderheilkd* 2002;150:1029.
- Steinmetz JP, Berger JP. Ultrasonography as an aid to diagnosis and treatment in a rural African hospital: a prospective study of 1,119 cases. *Am J Trop Med Hyg* 199;60:119-123.
- [No authors listed]. Future use of new imaging technologies in developing countries. Report of a WHO Scientific Group. *World Health Organ Tech Rep Ser* 1985;723:1-67.
- Palmer PE. Imaging equipment for small hospitals. *Trop Geogr Med* 1993;4:98-102.
- Leggat PA. Basic radiological system: a case study in 'appropriate technology for better health'. *Aust J Rural Health* 1997;5:87-89.
- Kongnyuy EJ, van den Broek N. The use of ultrasonography in obstetrics in developing countries. *Trop Doct* 2007;37:70-72.
- Seffah JD, Adanu RM. Obstetric ultrasonography in low-income countries. *Clin Obstet Gynecol* 2009;52:250-255.
- Harris RD, Marks WM. Compact ultrasound for improving maternal and perinatal care in low-resource settings: review of the potential benefits, implementation challenges, and public health issues. *J Ultrasound Med* 2009;28:1067-1076.
- Merten DF, Palmer PE, Sweet EM, Fendel H, Faure C, Fujioka M. Rational use of diagnostic imaging in paediatrics. The report of a World Health Organization Study Group. *Pediatr Radiol* 1989;19:216-218.
- Kalifa G, Bouras A, Reymond-Yeni A, Gendrel D. Imaging in pediatrics. Strategy and economic implications for the Third World [French]. *Ann Pediatr (Paris)* 1992;39:67-70.
- Adeloye A. Use of the Malawi shunt in the treatment of obstructive hydrocephalus in children. *East Afr Med J* 1997;74:263-266.
- Adeloye A. Management of infantile hydrocephalus in Central Africa. *Trop Doct* 2001;31:67-70.
- Spencer JK, Adler RS. Utility of portable ultrasound in a community in Ghana. *J Ultrasound Med* 2008;27:1735-4173.
- Weill Bugando University College of Health Sciences. Clinical Postgraduate Programmes: Curriculum for the Master of Medicine (MMed) in Paediatrics Degree Programme. Mwanza: Weill Bugando University College of Health Sciences, 2006/2007.
- Vangeenderhuysen C, Abdellahi MB, Isselmou S. Training midwives in developing countries in obstetric ultrasonography: goals and application [French]. *J Gynecol Obstet Biol Reprod (Paris)* 2002;31:100-106.
- Ferraioli G, Meloni MF. Sonographic training program at a district hospital in a developing country: work in progress. *AJR Am J Roentgenol* 2007;189:W119-122.