Heart murmurs recorded by a sensor based electronic stethoscope and e-mailed for remote assessment

L B Dahl, P Hasvold, E Arild, T Hasvold

Background: Heart murmurs are common in children, and they are often referred to a specialist for examination. A clinically innocent murmur does not need further investigation. The referral area of the University Hospital is large and sparsely populated. A new service for remote auscultation (telemedicine) of heart murmurs in children was established where heart sounds and short texts were sent as an attachment to e-mails.

Aim: To assess the clinical quality of this method.

Methods: Heart sounds from 47 patients with no murmur (n = 7), with innocent murmurs (n = 20), or with pathological murmurs (n = 20) were recorded using a sensor based stethoscope and e-mailed to a remote computer. The sounds were repeated, giving 100 cases that were randomly distributed on a compact disc. Four cardiologists assessed and categorised the cases as having “no murmur”, “innocent murmur”, or “pathological murmur”, recorded the assessment time per case, their degree of certainty, and whether they recommended referral.

Results: On average, 2.1 minutes were spent on each case. The mean sensitivity and specificity were 89.7% and 98.2% respectively, and the inter-observer and intra-observer variabilities were low (kappa 0.81 and 0.87), respectively. A total of 93.4% of cases with a pathological murmur and 12.6% of cases with an innocent murmur were recommended for referral.

Conclusion: Telemedical referral of patients with heart murmurs for remote assessment by a cardiologist is safe and saves time. Skilled auscultation is adequate to detect patients with innocent murmurs.

SUBJECTS AND METHODS
A mix of normal heart sounds (from subjects with no murmur or an innocent murmur) and sounds from patients with cardiac lesions (with pathological murmurs) were recorded at the University Hospital of Tromso. Up to five sounds from different locations in each patient were recorded separately by a sensor based electronic stethoscope (the Stethoscope, Medtron AS, Norway). The sounds were recorded using a sampling frequency of 22.1 K samples per second, mono, 16 bit dynamic resolution, and sent as a case by e-mail to a remote computer (PC) to be collected in a database and stored in separate files as a *.wav file (wave file). Information about the age of the patient and symptoms and other clinical signs were collected in a text file and e-mailed with the sound files. From this collection of sent and stored sounds, seven different cases without any murmur (mean age 4 years, range 2 months to 10 years) and 40 cases with a murmur—20 with physiological murmurs (mean age 5 years, range 1–13 years) and 20 with pathological murmurs (mean age 4 years, range 1 month to 13 years)—were randomly selected. Of the seven cases with no murmur, six were repeated three times, and one was repeated twice, equaling 20 cases. The 20 cases with innocent murmurs and the 20 cases with pathological murmurs were repeated twice, equaling 80 cases. These 100 cases were put in random order on a compact disc (CD). Of the innocent murmurs the pulmonary ejection murmur occurred...
Table 1  Reported time spent to assess and classify the cases

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>Sounds (n)</th>
<th>Percent</th>
<th>Cumulated</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>111</td>
<td>36.6</td>
<td>36.6</td>
</tr>
<tr>
<td>2</td>
<td>108</td>
<td>35.3</td>
<td>71.9</td>
</tr>
<tr>
<td>3</td>
<td>62</td>
<td>19.5</td>
<td>91.4</td>
</tr>
<tr>
<td>4</td>
<td>19</td>
<td>5.6</td>
<td>97.0</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>1.0</td>
<td>98.0</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>1.0</td>
<td>99.0</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>0.0</td>
<td>99.0</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>0.3</td>
<td>99.3</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>0.0</td>
<td>99.3</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>0.7</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table 2  Observers' sensitivity and specificity in classifying the cases

<table>
<thead>
<tr>
<th>Observers</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observer A</td>
<td>87.1</td>
<td>98.3</td>
</tr>
<tr>
<td>Observer B</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Observer C</td>
<td>85.0</td>
<td>96.5</td>
</tr>
<tr>
<td>Observer D</td>
<td>86.8</td>
<td>98.3</td>
</tr>
<tr>
<td>Mean</td>
<td>89.7</td>
<td>98.2</td>
</tr>
</tbody>
</table>

RESULTS

The four observers assessed 398 of the 400 cases, of which the time consumption was recorded in 303. One of the observers did not record the time spent on each case, but estimated the average time to categorise each case as two minutes. We excluded these from the estimation of the time consumption, thus basing our estimation on 303 cases. Of the cases with a time recording, the observers spent 2.1 minutes on average assessing each case. This included the time to retrieve the sound track(s), to listen through the recording(s), to categorise the case, and to record the category decided. Table 1 shows the distribution of time spent.

The observers had a mean sensitivity of 89.7% and a mean specificity of 98.2%. Table 2 shows the sensitivity and the specificity of each observer.

Table 3 shows the inter-observer variability (external variability) within pairs of observers. The mean of the sum of the kappa values of all the pairs was 0.81. Table 3 also gives the proportional variability (observed variability) of each category of heart sounds.

The intra-observer variability of each observer, when they blindly categorised randomly repeated cases, is shown as kappa estimations in table 4. The mean of the sum of the kappa values of all the observers' internal variability was 0.87. Table 5 shows all the observers' recommendations of referral to hospital for further investigation. Of the cases with accompanying text next to the image. For playback of the sounds we relied on the soundcard in the PC and the Microsoft Media Player found as a part of the Microsoft Windows 98 operating system.

The CD with the cases, a headset of high quality (AKG K-100), and a laptop PC (Toshiba Satellite 4090XCDT) computer were sent to a panel of four paediatric cardiologists at different hospitals in Norway. They listened to the sounds and recorded for each, on a provided form, the time needed to categorise each case into one of the following three categories: no murmur; innocent murmur; pathological murmur. They also recorded the degree of certainty in this categorisation and whether referral for further investigation was recommended or not.

The recorded data on the form were punched in an Epi Info database and analysed by Epi Info.

Table 3  Inter-observer variability in classifying the cases

<table>
<thead>
<tr>
<th>Pairs of observers</th>
<th>Kappa</th>
<th>Observed variability of each sound category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No murmur</td>
</tr>
<tr>
<td>A v B</td>
<td>0.88</td>
<td>(0.72 to 0.92)</td>
</tr>
<tr>
<td>A v C</td>
<td>0.89</td>
<td>(0.81 to 0.97)</td>
</tr>
<tr>
<td>A v D</td>
<td>0.78</td>
<td>(0.67 to 0.88)</td>
</tr>
<tr>
<td>B v C</td>
<td>0.79</td>
<td>(0.68 to 0.89)</td>
</tr>
<tr>
<td>B v D</td>
<td>0.80</td>
<td>(0.70 to 0.91)</td>
</tr>
<tr>
<td>C v D</td>
<td>0.77</td>
<td>(0.66 to 0.88)</td>
</tr>
<tr>
<td>Mean</td>
<td>0.81</td>
<td>(0.77 to 0.85)</td>
</tr>
</tbody>
</table>

95% confidence intervals in parentheses.

Table 4  Intra-observer variability in classifying the cases

<table>
<thead>
<tr>
<th>Observers</th>
<th>Kappa</th>
<th>Observed variability of each sound category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No murmur</td>
</tr>
<tr>
<td>A</td>
<td>0.97</td>
<td>(0.97 to 1.00)</td>
</tr>
<tr>
<td>B</td>
<td>0.89</td>
<td>(0.79 to 0.99)</td>
</tr>
<tr>
<td>C</td>
<td>0.87</td>
<td>(0.76 to 0.98)</td>
</tr>
<tr>
<td>D</td>
<td>0.73</td>
<td>(0.59 to 0.88)</td>
</tr>
<tr>
<td>All</td>
<td>0.87</td>
<td>(0.82 to 0.92)</td>
</tr>
</tbody>
</table>

95% confidence intervals in parentheses.
Table 5 Observers’ recommendation of referral

<table>
<thead>
<tr>
<th>Referral</th>
<th>No murmur (n=61)</th>
<th>Innocent murmur (n=151)</th>
<th>Pathological murmur (n=151)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>Yes</td>
<td>3</td>
<td>4.9</td>
<td>[1 to 13.7]</td>
</tr>
<tr>
<td>No</td>
<td>58</td>
<td>95.1</td>
<td>[86.3 to 99.0]</td>
</tr>
</tbody>
</table>

95% confidence intervals in parentheses.

Pathological murmurs (n = 160), 151 were classified. Ten of these cases (6.6%) were classified as “not recommended to be referred”. These cases consisted of three patients with moderate valvular pulmonary stenosis and two with moderate valvular aortic stenosis.

The observers reported a high degree of certainty when classifying the cases.

DISCUSSION

The present study shows that this sensor based electronic stethoscope allows digitalised heart sounds to be e-mailed easily, with maintained sound quality.1 It further indicates that telemedicine is a safe and convenient method for referral of heart murmurs in children for evaluation by paediatric cardiologists.

In our study the prevalence of cases with pathological heart sounds presented on the CD was 40%. This is a higher prevalence than what most referral hospitals experience. There is no true prevalence of pathology among the referrals, as this may vary as a function of referring doctors’ profiles of referrals. The variation in prevalence will change the pretest and post-test predictive values, but will have less effect on the sensitivity and specificity.15 We have therefore presented the method’s ability to select the cases with pathological murmurs among those with a cardiac lesion, and the cases with no or innocent murmurs among the healthy children by estimating the method’s sensitivity and specificity, and not the predictive values.

The transferred murmurs were assessed with a sensitivity and specificity close to or even higher than15 those reported when patients with heart murmurs are evaluated in person by specialists in paediatric cardiology. In a prospective series of 161 patients, with innocent or pathological heart murmurs being clinically examined by paediatric cardiologists, Smythe et al showed that the clinical examination alone has a sensitivity of 96% and a specificity of 95%.15 Rajakumar and coworkers reported a clinical evaluation of 128 heart murmurs by paediatric cardiologists and general paediatricians.15 They found no difference in sensitivity between the two groups (85% v 79%, p = 0.53). Paediatric cardiologists, however, had a higher specificity than the general paediatricians (76% v 55%, p = 0.001). In a study of the accuracy of clinical assessment of heart murmurs by general paediatricians, the mean sensitivity and specificity were 82% and 72%, respectively.15 All these figures are lower than those reported in our study. We therefore concluded that referring the heart sounds with a brief clinical interpretation of echocardiogram, and has proved to be useful.19,20 Participant as well as patient satisfaction with telemedicine has been evaluated.21,22 Systematic review of studies on patient satisfaction has however concluded that, as a result of improper evaluation methods, we still do not know whether patients are quite satisfied with telemedicine consultation.22 Will the parents of children with heart murmurs trust in this method? From our study it is not possible to answer this question. Much will probably depend on their confidence in their GP, and whether she/he will accept this way of referring a child with a heart murmur.

It is claimed that auscultation skills of paediatric residents are suboptimal.23 Reliance on the stethoscope has gradually decreased, and medical students are today spending less time on learning how to use the stethoscope properly than they did in the past.24 If telemedicine is accepted as a safe method to assess heart murmurs in children it may develop to the method of choice not only in rural, but also in urban areas. Linked to their telemedical reply the cardiologist may also provide the general practitioner with some simple advice on...
how to separate a pathological from an innocent murmur,2
and thus improve their auscultation skills.

Conclusion
The present study indicates that telemedicine consultations may develop into a safe and convenient method for remote assessment of heart murmurs in children. It has the potential for saving time and reducing inconvenience and cost. The study confirms that skilled auscultation alone is adequate to separate innocent from pathological murmurs in children.

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REFERENCES

TECHNOLOGICAL ADVANCES AND ASSESSMENT OF CHILDREN WITH MURMURS
History taking and clinical examination are fundamental skills in medicine which determine the need for further examination. Most murmurs detected by paediatricians come to notice as part of a routine examination (which is often seen as a “screening” examination) or during assessment of children with intercurrent illness. Some murmurs in neonates, many in infants, and most in childhood are benign or innocent. The challenge for the paediatrician is to separate the many innocent murmurs from the few which are significant.3

Many paediatricians find auscultation difficult, hence the frequency of referral of children to paediatric cardiologists for a clinical opinion and further investigation. The diagnosis of an innocent murmur requires the absence of symptoms referable to the cardiovascular system, the absence of other abnormal cardiovascular signs, and recognition of the characteristic sound of an innocent murmur as opposed to a pathological murmur. Paediatricians can readily take a history, examine the pulses, and measure the blood pressure, but sometimes lack confidence in differentiation between innocent and important murmurs. This may result in part from a lack of practice—the individual paediatrician encounters relatively few innocent murmurs and fewer pathological murmurs. Studies of the clinical performance of paediatricians in assessment of murmurs give conflicting results,4 but usually find high diagnostic accuracy,5. However, given the low disease prevalence, this may be falsely reassuring.

Some paediatricians acquire skill in echocardiography, but it takes time and practice to be able to recognise subtle but important abnormalities with confidence.6 The use of an adult echocardiography service for examination of babies and children in a general hospital may also be misleading as important diagnoses may be overlooked.7

Because paediatric cardiologists mostly work in a few larger centres, paediatricians and their patients do not necessarily have ready access to a specialist opinion. However, recent technological advances have provided access to specialist paediatric cardiologists without having to refer or transfer the patient. The main use of this technology thus far has been in investigation. Thus an opinion can be sought on an ECG sent via fax or e-mail; telemedicine transmission of echocardiographic images also provides direct access to a specialist interpretation.8

Dah1 et al describe a technique for sending a recording of heart sounds via e-mail, providing a specialist opinion on auscultation without the need for the patient to travel. Although the project comes from northern Norway, which has a sparse population spread over a large area, the technique is obviously applicable more widely. A logical further step might even be to replace the paediatric cardiologist by computer as well—a recent report shows 100% sensitivity and specificity of an artificial neural network in recognition of murmur, a better performance than the average paediatric cardiologist.9

One worry is that paediatricians may become deskilled if they never have to make a decision about the diagnosis in a child with a murmur. Concern has also been expressed recently that paediatricians in training lack the skills required for recognition and assessment of murmurs. The best solution

[www.archdischild.com](http://www.archdischild.com)
overall is not to give up and replace auscultation with
electronic specialist opinion, but rather to teach and develop
clinical skills, even in an era of rapid technological advance
and evolution.1

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ARCHIVIST

Children seeking asylum

In 1991, 3349 unaccompanied children and adolescents (under 18 years) applied for asylum in the
United Kingdom (Carolyn Bann and Ruth Tennant. National Children's Bureau 2002; Highlight no 190.
ISSN: 1365–9081). Towards the end of 2001 there were 4196 such children in London: almost a quar-
ter of them (987) were under 16 years old. Most come from Yugoslavia, Afghanistan, Somalia, Sri Lanka,
or Turkey.

Children travel alone to seek asylum because their desperate parents have sent them away from dan-
ger or because they are orphans or separated from their parents. Some, from West Africa or China, it is
reported, are the victims of child traffickers for sexual exploitation. Predictably, when they arrive in the
UK the children are frightened, lonely, confused, and downhearted. Despite a 2001 Home Office White
Paper recommending that they be given proper advice and care from the time of their arrival, some appear
to have been left to their own devices and some have slept overnight on the airport concourse. Government
policy is that these children should not be detained but it seems that this policy has not always
worked out in practice and the Refugee Council has worked with at least 135 unaccompanied children in
detention since the beginning of 1997. Most children applying for asylum are not given refugee status but
instead are granted leave to remain in the UK only until they are 18. Local social services departments are
responsible for the care of these children but several recent reports have pointed to deficiencies in the
provisions made.

Caring for their health presents difficulties. Their previous medical and immunisation histories are
usually unknown. They inevitably have emotional problems because of their separation from family,
friends, and their own culture. They may experience antipathy and prejudice in the local population
and psychological problems may include post-traumatic stress disorder. Physical conditions vary with the
countries of origin but malnutrition, tuberculosis, hepatitis, malaria, schistosomiasis, and HIV infection
may need to be considered. In addition, the children may be living in poor accommodation (the charity
Shelter claimed that private rented accommodation provided for asylum seekers was “unfit for human
habitation” in one case in six). Finding a school place may be difficult and school examinations times of
great anxiety, and the provision of legal advice may be inadequate.

These children often come from places where civilisation has broken down. It should be a mark of our
civilisation that children receive kindness and compassion whoever they are and wherever they come from.