Prevalence of hypertension in children after early repair of coarctation of the aorta: a cohort study using casual and 24 hour blood pressure measurement

J J O’Sullivan, G Derrick, R Darnell

Objective: To study the prevalence of hypertension in a cohort of patients using the current strategy of repair in early childhood.


Intervention: Casual (mean of three resting readings) and 24 hour blood pressure were measured in 119 children and compared with data from 1034 normal controls. The arch repair and left ventricular parameters were assessed using Doppler echocardiography.

Results: Median ages at first intervention and at blood pressure measurement were 0.2 years (inter-quartile range 0.04–2.0) and 12.0 years (9.0–14.5), respectively. Doppler velocity in the descending aorta was significantly associated with blood pressure (r = 0.28, p = 0.002 for casual systolic blood pressure [SBP]; r = 0.26, p = 0.005 for mean 24 hour SBP). Patients were classified as having "no" (n = 70), "mild" (n = 49) or "moderate" (n = 4) arch obstruction. Casual SBP was > 95th centile in 28% (34 of 119) overall and in 30% (36 of 119) overall and in 21% (15 of 70) of the no arch obstruction group. Mean 24 hour SBP was > 95th centile in 30% (36 of 119) overall and in 19% (13 of 70) of the no arch obstruction group. The sensitivity and specificity of casual SBP in detecting increased 24 hour SBP were 66% and 88%, respectively.

Conclusions: This unique study of a large cohort of patients treated for coarctation in early childhood showed that a disappointingly high prevalence of hypertension is already apparent in children aged 7–16 years in the absence of significant arch obstruction, whether assessed by 24 hour or by casual blood pressure measurement.
All of the children studied were considered to have had a satisfactory coarctation repair and none were being actively considered for reintervention. However, they could be divided into a group with no residual obstruction and a group with mild residual coarctation. No residual obstruction was defined as an arch velocity of < 2.5 m/s without a diastolic tail and a widely patent arch on cross sectional echocardiography. Daytime blood pressure was defined as that between 0700 and 2200. Normal 24 hour blood pressure data were obtained from the large study using similar monitoring equipment from our department. Normal casual blood pressure data were obtained from published data. The statistical package R was used for all statistical testing including z tests and t tests for testing the significance of Pearson’s correlation coefficient.

RESULTS
This study was confined to children who were < 16 years and > 6 years old at the time of the study (1999–2000). There were 166 children born between 1983 and 1992 (inclusive) on the database with a diagnosis of coarctation of the aorta. Of the total cohort 20 had died. Of the 146 long term survivors, nine could not be contacted and 11 did not wish to participate. This was mainly because of anticipated difficulties with returning the monitor on the following day or parental concerns with the monitor on the following day or parental concerns with regard to their children wearing the blood pressure monitor for 24 hours. The remaining 126 children were studied. In seven cases the data from the 24 hour monitor were of poor quality and were not used. The data from 119 children are presented.

The median age of the children at the time of blood pressure and Doppler measurements was 11.1 years (interquartile range (IQR) 8–14 years). Other cardiac lesions were present in 38% (46 of 119) of the participants; these were ventricular septal defect in 22% (27 of 119), aortic stenosis in 6% (7 of 119), mitral valve disease in 5% (6 of 119), and transposition of the great arteries in 5% (6 of 119). The median age at operation for the total group was 0.22 years (IQR 0.04–2.02 years) but this was not significant (p = 0.13). There was no significant difference in the age at intervention between the non-obstructed and mildly obstructed groups (1.86 v 1.87 years).

Casual blood pressure
Casual blood pressure in the coarctation patients was compared with the normal resting values derived from six European studies. Of the 119 children who had coarctation repair, 34 (28.5%) had a mean resting SBP reading > 95th centile of the normal population (table 2). When the analysis was confined to those operated on in infancy the proportion who had significantly increased casual blood pressure did not change significantly (20 of 77; 26%). When the analysis was confined to those with no residual obstruction group but this was not significant (p = 0.13). There was no significant difference in the age at intervention between the non-obstructed and mildly obstructed groups (1.86 v 1.87 years).

Twenty four hour blood pressure
The 24 hour mean SBP of each child was compared with the normal 24 hour blood pressure data obtained using the same blood pressure device from a large group of 1034 normal schoolchildren aged from 6–16 years. Overall, the coarctation group had significantly higher mean 24 hour, daytime, and night time SBP (all p < 0.001). The differences remained statistically different (all p < 0.001) when those with mild arch obstruction were removed.

Thirty six children (36 of 119; 30%) had a mean 24 hour SBP > 95th centile of the age specific normal population. When the analysis was confined to those operated on in infancy the proportion who had significantly increased 24 hour blood pressure did not change significantly (21 of 77;
months from repair in infancy. The relatively short follow up and the young age at blood pressure assessment makes the interpretation of these findings difficult.

The feasibility of 24 hour blood pressure measurement in children offered the potential of more reliable blood pressure assessment in this age group, but the diagnosis of hypertension using this technology has been hampered by the lack of reliable 24 hour normal data. The studies that have been carried out using this technology (table 3) found a significantly higher mean 24 hour blood pressure in coarctation patients than in controls. Some of these studies have used control data from the literature to define hypertension using the 24 hour blood pressure results and the prevalence of hypertension varies in these studies from 19–45%. However, these studies are of selected patients and cannot be used as a reliable measure of the prevalence of hypertension in this population.

The availability of a large volume of normal 24 hour blood pressure data in our department allowed us to use this method to study a cohort of children who were now aged 7–15 years and who had treatment of coarctation in early childhood. The children were being studied an average of 9.5 years following treatment of coarctation of the aorta. When blood pressure was assessed as a resting or casual measurement the prevalence of systolic hypertension (mean reading > 95th centile) was 28% (34 of 119). Using the 24 hour mean the prevalence of systolic hypertension was 30% (36 of 119). If those with mild arch obstruction were excluded, the prevalence of hypertension using the casual and 24 hour measurements was 21% and 19%, respectively. As outlined above there are no similar studies in the literature for comparison, but for completeness table 3 summarises data from studies of blood pressure in selected coarctation patients.

There is evidence in the adult literature that 24 hour blood pressure is a better predictor of end organ damage and therefore provides a better measure of blood pressure than casual readings. This has not been conclusively proved in children but there are studies that have found a significant association between 24 hour blood pressure and left ventricular dimensions. One further issue addressed in our study was the sensitivity of an increased casual blood pressure measurement in screening for increased 24 hour blood pressure. Increased casual SBP has good specificity (over 85%) and is therefore clinically useful in this regard. Casual blood pressure measurement is not very sensitive (66%) and cannot be relied on as a research tool to measure the prevalence of increased 24 hour blood pressure in the coarctation population.

The correlation between ventricular septal thickness and mean 24 hour blood pressure shown by us and other authors may support the use of antihypertension treatment in these patients. However, the inability to find abnormal diastolic function and the lack of outcome data make it difficult to recommend lifelong treatment of increased blood pressure in these children. Twenty four hour blood pressure has

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**Table 3** Comparison between recent studies on blood pressure in patients with coarctation of the aorta and the present study

<table>
<thead>
<tr>
<th>Author and reference</th>
<th>Number of participants</th>
<th>Mean (SD) age at operation (years)</th>
<th>Mean follow up (years)</th>
<th>Hypertension determined by casual SBP (%)</th>
<th>Controls</th>
<th>Hypertensive 24 h SBP (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Giordano20</td>
<td>38</td>
<td>Children</td>
<td>2.6 (3)</td>
<td>16</td>
<td>Lit</td>
<td>34</td>
</tr>
<tr>
<td>Leandro21</td>
<td>20</td>
<td>5.5 (4.3)</td>
<td>9.2 (3.1)</td>
<td>20</td>
<td>NA</td>
<td>45</td>
</tr>
<tr>
<td>Ergoli22</td>
<td>18</td>
<td>5.1 (4.8)</td>
<td>2.5 (1.9)</td>
<td>18</td>
<td>NA</td>
<td>45</td>
</tr>
<tr>
<td>Parrish23</td>
<td>11</td>
<td>6.0 (1.0)</td>
<td>10.1 (1.0)</td>
<td>NA</td>
<td>15</td>
<td>45</td>
</tr>
<tr>
<td>Hauser24</td>
<td>55</td>
<td>2.8 (2.2)</td>
<td>7.9</td>
<td>45</td>
<td>Lit</td>
<td>19†</td>
</tr>
<tr>
<td>Johnson25</td>
<td>21</td>
<td>5.5 (4.6)</td>
<td>9.4 (4.9)</td>
<td>27</td>
<td>Lit</td>
<td>29†</td>
</tr>
<tr>
<td>Present study</td>
<td>119</td>
<td>0.2 (0.04–2.0)†</td>
<td>9.5 (1.1–12.8)†</td>
<td>30</td>
<td>1034</td>
<td>19</td>
</tr>
</tbody>
</table>

*If mean 24 hour blood pressure was not given, the prevalence of daytime hypertension was used; †median and interquartile range.

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27%). When those with mild arch obstruction were excluded (table 2), 13 of 70 (18.5%) had mean 24 hour readings > 95th centile of the normal population.

**Can casual blood pressure measurement identify children with high 24 hour blood pressure?**

Table 2 presents the sensitivity and specificity of an increased casual blood pressure measurement. An increased casual blood pressure has good specificity (88%) in detecting an increased 24 hour blood pressure but has a relatively poor sensitivity (66%). It can be seen that the sensitivity and specificity of casual blood pressure measurement in detecting increased 24 hour pressure do not change significantly when the children with no residual obstruction are analysed separately.

**Blood pressure and left ventricular measurements**

The mean 24 hour blood pressure was correlated with certain Doppler echocardiographic measures of left ventricular function. There was no significant correlation between the mitral inflow velocities (E:A ratio) and mean 24 hour blood pressure (r = 0.026, p = 0.78, n = 117). The correlation between isovolumic relaxation time and 24 hour blood pressure was also not significant (r = −0.091, p = 0.36, n = 103). There was a significant correlation between the interventricular septal thickness and 24 hour blood pressure (r = 0.315, p = 0.001, n = 104).
been shown to track better than casual blood pressure in adolescence, but longer term data are needed before we can confidently predict adult hypertension from childhood readings.

To our knowledge this is the first study of the prevalence of hypertension in children with coarctation of the aorta operated on in the 1980s and 1990s. Our data show that a high prevalence of abnormal 24 hour blood pressure is already apparent in later childhood after successful treatment of the coarctation in early life. The study did not investigate the reasons for hypertension after a good arch repair but the observation that arterial reactivity is impaired in adults who have had a neonatal repair is in keeping with our findings.

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