Ultrasound in Med. & Biol., Vol. 40, No. 12, pp. 2786–2793, 2014

0301-5629/$ - see front matter

http://dx.doi.org/10.1016/j.ultrasmedbio.2014.07.011

● *Original Contribution*

DUPLEX ULTRASOUND FINDINGS BEFORE AND AFTER SURGERY IN CHILDREN AND ADOLESCENTS WITH RENOVASCULAR HYPERTENSION

Adina Voiculescu,*† Andreas Heusch,‡ Philip Düppers,§ Siamak Pourhassan,§ Dirk Klee,¶ Lars C. Rump,† and Wilhelm Sandmann§

* Renal Division, Brigham and Women's Hospital, Boston, Massachusetts, USA; † Nephrology Department, University Hospital Dusseldorf, Dusseldorf, Germany; ‡ Paediatric Cardiology and Pulmonary Medicine, Helios Klinikum Wuppertal, Wuppertal, Germany; § Department of Vascular Surgery and Kidney Transplantation University Hospital Dusseldorf, Dusseldorf, Germany; and ¶ Diagnostic and Interventional Radiology, University Hospital Dusseldorf, Dusseldorf, Germany

(*Received* 14 *January* 2014; *revised* 7 *July* 2014; *in final form* 16 *July* 2014)

Abstract—We report our experience with duplex ultrasound in young patients with renal artery stenosis (RAS) or middle aortic syndrome (MAS) before and after surgery (1995 and 2009). Of 36 patients (mean age: 13 ± 7 y), 21 had RAS and 15 had MAS. For patients with RAS, the V_{max} in the affected artery was 350 ± 111 cm/s before surgery and 145 ± 55 cm/s after surgery. The resistance index was 0.46 ± 0.1 in the post-stenotic kidney and increased to 0.60 ± 0.08 after revascularization. Determination of the flow profile in the iliac artery revealed triphasic flow. In individuals with MAS, V_{max} in the aorta was 323 ± 98 and the resistance index in both kidneys was low, even in the absence of RAS. The flow profile in the iliac arteries was monophasic before surgery and became triphasic after surgery. Duplex ultrasound is useful for the evaluation of children and young adults both pre- and post-surgery. Duplex ultrasound criteria for RAS in adults appear to be applicable in children and young adults also. The diagnostic evaluation of suspected renal vascular disease should include assessment of the aorta and the flow profile in the iliac arteries, as this could help differentiate between aortic and isolated renal artery stenosis. (E-mail: avoiculescu@partners.org) © 2014 World Federation for Ultrasound in Medicine & Biology.

Key Words: **Renal artery stenosis, Mid-aortic syndrome, Abdominal aortic coarctation, Doppler, Renovascular hypertension, Diagnostic tests.**

INTRODUCTION

Although the role of obesity in the development of childhood hypertension is increasing, high blood pressure in children and young adults is most often secondary to renal and renovascular disease. Renal parenchymal disease is the most common etiology (60%–70%) (Bartosh and Aronson 1999; Flynn 2001; Gomes et al. 2011), followed by vascular disease, including thoracic aortic coarctation, middle aortic syndrome (MAS) and renal vascular disease, which accounts for about 10%–20% of hypertension in children and adolescents (Falkner and DeLoach 2009).

Renovascular hypertension can be defined as hypertension resulting from a lesion that restricts blood flow to one or both kidneys (Dillon 1997). Renal artery stenosis (RAS) in children represents a wide spectrum of heterogeneous diseases, among which fibromuscular dysplasia, with bilateral and segmental disease and possible involvement of small intrarenal arteries, occurs most often. Other causes result from the narrowing of the abdominal aorta, from which stenosed renal and visceral arteries can arise. When aortic coarctation is located proximal to the renal arteries, kidney perfusion is affected, and therefore, as with isolated RAS, this malformation induces a "renovascular" hypertension.

When renovascular disease is strongly suspected in children, intra-arterial digital subtraction angiography (DSA) is recommended and is considered the gold standard for diagnosis (Tullus 2011). Duplex ultrasound (DUS), nuclear scans, with or without angiotensin-converting enzyme inhibition, spiral computed tomography and magnetic resonance angiography (MRA) are available as non-invasive diagnostic tests (Luma and Spiotta 2006; Tullus et al. 2008). As with all screening methods, there may be false-positive and -negative findings, and in selected cases, DSA is thought to be necessary

Address correspondence to: Adina Voiculescu, Renal Division, Department of Medicine, Brigham and Women's Hospital, Harvard Medical School, 75 Francis Street, Boston, MA 02115, USA. E-mail: avoiculescu@partners.org

irrespective of the results of non-invasive tests. Few authors have reported the results of renal DUS in this distinct group of patients with renovascular hypertension (Brun et al. 1997; Castelli et al. 2014; Chhadia et al. 2013; Kchouk et al. 1997; McLeary and Rouse 1996). As ultrasound is non-invasive and relatively inexpensive, it has advantages over the other non-invasive diagnostic tests.

The primary treatment of renovascular hypertension in children consists of pharmacologic blood pressure control. However, medical treatment alone is often insufficient to control hypertension adequately, leaving those children exposed to life-threatening events such as cerebrovascular accidents, cardiac hypertrophy and congestive heart failure. Once the diagnosis is established, intervention in the form of endovascular procedures or surgery may be necessary (Lacombe 2011; Shroff et al. 2006; Srinivasan et al. 2010; Stadermann et al. 2010; Stanley et al. 2006). In contrast to adults, lesions found in this age group are often complex, more peripheral and not always amenable to percutaneous angioplasty. Therefore, surgical procedures are often required, with the goal of reconstructing the anatomy. Surgical procedures include renal artery re-implantation, arterial reconstruction with autologous or synthetic grafts, autotransplantation and nephrectomy (Bleacher et al. 1997; Chalmers et al. 2000; Lillehei and Shamberger 2001; O'Neill et al. 1995; Stadermann et al. 2010; Stanley et al. 2006).

The purpose of this article is to describe DUS findings before and after surgery in children and adolescents with renovascular disease. We were particularly interested in assessing the feasibility of the technique, including visualization of stenoses in the renal arteries and the aorta, defining indirect and direct criteria for the detection of renal artery stenosis in children and identifying parameters that may help differentiate renal artery and aortic disease.

METHODS

Patients

We performed a retrospective analysis of a cohort of all children and adolescents who were referred for reconstructive surgery between January 1995 and January 2009 for renovascular hypertension caused by RAS or MAS. All patients had already been diagnosed with RAS or MAS before hospitalization, and most of them were referred to our center from other hospitals. Several patients had received prior unsuccessful endovascular treatment and presented with recurrent stenosis or complications after intervention. DUS was performed in all patients as a standard of care to obtain data that would allow good post-operative follow up using non-invasive monitoring. DUS was performed 1–2 d before surgery and immediately post-surgery, as well as before discharge from the hospital (interval of 5–14 d after surgery, mean = 7 d). All DUS studies were performed in the Nephrology Ultrasound Laboratory by a specialized non-pediatric nephrologist (A.V.) who was the director of the Renal Ultrasound Laboratory at the University of Dusseldorf for several years. The Renal Division of the University of Dusseldorf has a specialized Ultrasound Laboratory where nephrologists are trained for a minimum of 6 mo to perform abdominal ultrasound, including renal and renovascular studies. The institutional review board at the University of Dusseldorf approved this study as a retrospective analysis, and therefore, informed consent was not required.

Most patients presented having already had angiograms performed at an outside institution. Patients who presented with MRAs only underwent DSA either in the catheter lab of the Pediatric Cardiology Department or in the Department of Diagnostic and Interventional Radiology. Fibromuscular dysplasia was diagnosed either on the basis of typical angiographic appearance and/or after pathologic examination.

After surgery, all patients underwent DUS as described above. In selected cases, MRA or DSA was also performed.

Blood pressure values, antihypertensive medications and estimated glomerular filtration rate (eGFR) values 1 d before surgery and at discharge from the hospital were recorded and used for the analysis.

Duplex ultrasound examination

Ultrasound examinations were performed with the unselected use of two devices (Siemens Elegra, Erlangen, Germany, and Toshiba Aplio, Neuss, Germany). Patients were studied in supine position using a 3.5-MHz-phased-array transducer. From the midline approach, maximal flow velocities within the renal arteries were obtained at angles of insonation less than 60°. A second approach was performed from the side, with the patient in a lateral decubitus position. Next, Doppler spectral waveforms were recorded from the interlobar arteries in the upper, middle and lower portions of the cortex. Peak systolic velocity (V_{max}) and diastolic velocity (V_{min}) were obtained to calculate the resistance index (RI) using the equation RI = $(V_{max} - V_{min})/V_{max}$. An average RI was calculated from at least three measurements per kidney. In case of a difference of RI >0.05 within a kidney, values were also reported individually, and this finding was interpreted as either the presence of an accessory artery with stenosis or a segmental artery stenosis for the artery feeding that particular region.