Suprasternal Notch Echocardiography: A Two-dimensional Technique for Evaluating Congenital Heart Disease

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SUMMARY Two-dimensional suprasternal notch echocardiography was performed in 1033 patients, ages 1 day to 18 years. For the long-axis suprasternal notch view, the transducer was positioned in the suprasternal notch and angled to obtain a plane passing between the right nipple and left scapular tip. In this view, the entire aortic arch, vessels to the head and neck, right pulmonary artery and right bronchus were imaged. The long-axis view was useful for evaluating coarctation and interruption of the aorta, hypoplastic left heart, aortic and pulmonic stenosis and cervical aortic arch. For the short-axis suprasternal notch view the transducer was positioned in the suprasternal notch and angled to obtain a coronal body plane. In this view the transverse aorta, right pulmonary artery, left atrium, innominate veins and superior vena cava were imaged. The short-axis view was useful in the evaluation of children with increased or decreased pulmonary blood flow, persistent left superior vena cava, total anomalous pulmonary venous return to the right superior vena cava, and superior vena caval obstruction after Mustard's operation. In the evaluation of children with congenital heart disease, the suprasternal notch views added significant information to the two-dimensional echocardiographic examination.

M-MODE echocardiographic examination from the suprasternal notch is a well-established technique for evaluating the transverse aorta, right pulmonary artery and left atrium. Using M-mode suprasternal notch echocardiography, Allen and colleagues found that the ratio of the transverse aortic arch diameter to the right pulmonary artery diameter was useful in the evaluation of certain forms of congenital heart disease. After the introduction of two-dimensional echocardiography, long-axis and short-axis planes were described for imaging cardiac structures from the suprasternal notch by two-dimensional echocardiography. Coarctation of the aorta is the only form of congenital heart disease that has been extensively evaluated with two-dimensional suprasternal notch echocardiography. In this report we describe the normal anatomic structures seen in the two-dimensional suprasternal notch planes and illustrate the usefulness of the suprasternal notch planes in evaluating children with congenital heart disease.

Materials and Methods

We evaluated 1033 patients from the suprasternal notch as part of the routine two-dimensional echocardiographic examination. The patients were 1 day to 18 years old. The diagnosis was confirmed by subsequent cardiac catheterization in 527 patients. In the remainder, the diagnosis was confirmed by a combination of the clinical evaluation, electrocardiography, roentgenography and M-mode echocardiography.

Suprasternal notch echocardiography was performed with a Varian Associates 80° phased-array sector scanner (3.5-MHz transducer) or a Toshiba SSH 10A Sonolayergraph (2.4-MHz transducer). The patients were examined in the supine position with a pillow placed under the shoulders so as to extend the neck. Often the patient's head was turned slightly to the left in order to gain access to the suprasternal notch. In some patients contrast echocardiography was performed with a bolus of 2–5 ml of normal saline during cardiac catheterization to verify certain anatomic features.

For the long-axis suprasternal notch view the transducer was positioned in the suprasternal notch and angled to obtain a plane passing between the right nipple and left scapular tip (fig. 1A). In this plane the right pulmonary artery was seen in cross-section as it courses beneath the aortic arch. To visualize the left pulmonary artery from the long-axis suprasternal notch view, the transducer was tilted slightly to the patient's left (fig. 1B). For the short-axis suprasternal notch view, the transducer was placed in the suprasternal notch parallel to the sternum and a coronal body plane was imaged (fig. 2). In this view the transverse aorta, right pulmonary artery and superior vena cava were imaged. With a slight rightward and anterior tilt of the transducer the superior vena cava–right atrial junction and ascending aorta were seen.

The two-dimensional echocardiographic examinations were recorded on videotape for later analysis at real-time or slow speeds. The figures presented here were taken from Polaroid photographs of stop-action, single-frame images from the videotape recordings. As a result, the photographs lack the integrated image and visual appreciation of motion normally present in the real-time recordings.

Results

We performed suprasternal notch echocardiographic examination in 1033 patients. Technically adequate imaging of the suprasternal notch planes was possible in 93% of these patients.
The Normal Image

In 279 patients the cardiac structures seen by suprasternal notch echocardiography were normal. The echocardiographic findings were confirmed by cardiac catheterization in 24 of these patients. The remaining 255 patients were confirmed as being normal by complete physical examination, roentgenography, electrocardiography and M-mode echocardiography. In the long-axis suprasternal notch view the entire aortic arch and vessels to the head and neck were visualized (fig. 3A). Frequently, the aortic valve leaflets were seen (fig. 3B). The right pulmonary artery was imaged in cross section as it coursed beneath the aortic arch, and the right mainstem bronchus (an eparterial bronchus) was imaged as a circular area of densely reflected echoes situated just above the right pulmonary artery. In addition, the left innominate vein, which courses from left to right in front of the vessels to the head and neck, was seen in cross section as a circular structure superior to the transverse aorta and anterior to the innominate artery.

When the standard long-axis suprasternal notch plane was tilted slightly to the patient's left, the transverse aorta, descending aorta and left pulmonary artery were visualized (fig. 4). In this view the left pulmonary artery and its junction with the main...
pulmonary artery were imaged in a tangential section and, therefore, assumed a characteristic comma shape. Because the left mainstem bronchus is a hyparterial structure, no densely reflected echoes were seen superior to the left pulmonary artery as was seen superior to the right pulmonary artery. Often the left atrium and left atrial appendage were imaged in this projection (fig. 5).

In the short-axis suprasternal notch view, the transverse aorta was seen in cross-section as an anterior circular structure (fig. 6). Inferior to the transverse aorta the right pulmonary artery was seen in a longitudinal section along its entire length. On the patient’s right the first branches of the right pulmonary artery were present. In the normal patients, the diameter of the transverse aorta was as large or slightly larger than the diameter of the right pulmonary artery. Inferior to the right pulmonary artery, the left atrium and, occasionally, the upper pulmonary veins, were imaged. Also, the left innominate vein was seen coursing superior to the transverse aorta from left to right. On the patient’s right the right and left innominate veins were seen at their junction with the superior vena cava (fig. 7). The superior vena cava coursed vertically alongside the transverse aorta. With slight anterior tilt of the transducer the superior vena cava–right atrial junction was imaged alongside the ascending aorta and aortic valve leaflets (fig. 8).

Abnormalities of the Systemic Veins

In the short-axis suprasternal notch view in 16 patients, an anomalous vessel was seen coursing vertically alongside the transverse aorta on the patient’s left side (fig. 9). This vessel represented a persistent left superior vena cava. In the 12 of the 16 patients who underwent cardiac catheterization the echocardiographic diagnosis of left superior vena cava draining to the coronary sinus was confirmed. The remaining four patients did not undergo cardiac catheterization; however, the echocardiographic diagnosis of a left superior vena cava draining to the coronary sinus was confirmed in these patients by left-arm vein contrast injection. The left superior vena cava was imaged best when the transducer was tilted slightly to the patient’s left in the short axis suprasternal notch view. Of the 12

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**Figure 3.** (A) Normal long-axis suprasternal notch view. The entire aortic arch (AO) is imaged. The right and left subclavian arteries (RSA and LSA) and the right and left common carotid arteries (RCC and LCC) are visualized. Beneath the aortic arch the right pulmonary artery (RPA) and the right mainstem bronchus (RB) are seen in cross section. The left innominate vein (IN) is also seen in cross section superior to the transverse Ao. (B) Normal long-axis suprasternal notch view illustrating the appearance of the aortic valve leaflets (V) in this plane. a = anterior; s = superior.

**Figure 4.** Long-axis suprasternal notch plane with the transducer angled toward the patient’s left in order to image the left pulmonary artery (Lpa). The Lpa and its junction with the main pulmonary artery are seen in tangential section and appear comma shaped. No eparterial bronchus is seen. a = anterior; ao = aorta; s = superior.
Figure 5. (A) Long-axis suprasternal notch view of the transverse aorta (ta) and left pulmonary artery (lpa) in a patient with double outlet right ventricle. The left atrium (la) is seen below the lpa. (B) Contrast suprasternal notch echocardiography in the same patient reveals a large right-to-left shunt. The area of the ta and lpa are filled with echoes that arise from the microcavitations produced during the saline injection. The la remains free of contrast echoes. The fingerlike projections from the superior aspect of the la could represent pulmonary veins or left atrial appendage.

Patients with left superior vena cava draining to the coronary sinus who underwent cardiac catheterization, two were found to have an absent right superior vena cava. Absence of the right superior vena cava in the short-axis suprasternal notch view was noted before cardiac catheterization in these two patients (fig. 9).

In the short-axis suprasternal notch view in two patients with situs ambiguous, superior venae cavae were imaged along both sides of the transverse aorta. At cardiac catheterization these patients had bilateral superior venae cavae draining to both atria (fig. 10).

In the short-axis suprasternal notch view in one cyanotic newborn, a large vascular collar was seen surrounding the transverse aorta (fig. 11). The echocardiographic diagnosis of total anomalous pulmonary venous return to the right superior vena cava via a left vertical vein was confirmed by cardiac catheterization. In the suprasternal notch echocardiogram in this infant, an extremely small left atrium was also visualized.

In three newborn infants with a vein of Galen fistula confirmed by angiography, the superior vena cava and innominate vessels were very enlarged in the short-axis suprasternal notch view. During a suprasternal notch contrast study, microcavitations from a peripheral saline injection filled the superior vena cava and immediately opacified the aorta because of right-to-left atrial shunting. Several heart beats later the superior vena cava again opacified from microcavitations that had passed from the cerebral arteries to the cerebral veins by way of the vein of Galen fistula.

We examined 29 infants after Mustard's operation for d-transposition of the great arteries who had also undergone cardiac catheterization. In 25 infants, suprasternal notch echocardiography was normal except for the presence of the baffle in the area of the transverse aorta.
**Figure 7.** (A) Short-axis suprasternal notch view obtained during cardiac catheterization in a patient with normal suprasternal notch anatomy. The catheter (C) is present in the right innominate vein (Rln). Ao = aorta; l = left; LA = left atrium; LIn = left innominate vein; RPA = right pulmonary artery; s = superior; SVC = superior vena cava. (B) A bolus of saline was injected via the catheter and echoes arising from the contrast injection were seen filling the Rln and SVC, thereby verifying these structures.

**Figure 8.** Short-axis suprasternal notch plane with the transducer tilted anteriorly in order to visualize the ascending aorta (ao) and the superior vena cava-right atrial (svc-ra) junction. The white arrow indicates an aortic valve leaflet. r = right; s = superior.

**Figure 9.** (top) Frame from a cineangiogram in the anteroposterior projection in a patient with absent right superior vena cava. The right innominate vein (ri) drains into a left superior vena cava (lsvc), which empties into the coronary sinus. (bottom) Short-axis suprasternal notch view from the same patient. The usual feature of the left innominate vein coursing toward the patient's right side superior to the transverse aorta is absent. Instead, the right innominate vein (ri) courses from right-to-left superior to the transverse aorta (a). On the patient's left the junction of the ri and a left superior vena cava (lsvc) are imaged. la = left atrium; rpa = right pulmonary artery.

During contrast echocardiography from a peripheral arm vein in eight of these 25 infants, microcavitations passed directly from the superior vena cava to the systemic venous atrium. In the other four patients, echoes from a contrast injection were seen filling the innominate veins and superior vena cava; however, the systemic venous atrium filled from
systolic pressure difference across the coarctation ranged from 15–80 mm Hg. In seven patients the suprasternal notch echocardiograms were interpreted as normal; however, at cardiac catheterization a mild coarctation of the aorta was found. In these seven patients, the systolic pressure difference across the coarctation ranged from 5–25 mm Hg.

In 10 patients with interruption of the aortic arch confirmed by cardiac catheterization, the long-axis suprasternal notch view showed the ascending aorta and descending aorta without an intervening segment of transverse aorta (fig. 13). In three patients, the systolic pressure difference across the coarctation was 15–80 mm Hg.

Abnormalities of the Aorta and Aortic Arch

In 30 patients with coarctation of the aorta confirmed by cardiac catheterization, the long-axis suprasternal notch view showed an area of narrowing in the descending aorta, followed by an area of poststenotic dilatation (fig. 12). In these patients, the inferior vena cava. In these four patients, an area of superior vena cava obstruction was not visualized directly by suprasternal notch echocardiography.

**Figure 10.** Short-axis suprasternal notch view from a patient with bilateral superior venae cavae (SVC) imaged along both sides of the transverse aorta (a). i = innominate vein; la = left-sided atrium; rpa = right pulmonary artery.

**Figure 11.** Short-axis suprasternal notch view from a 1-day-old infant with total anomalous pulmonary venous return to the superior vena cava (SVC). The pulmonary veins drain via a left vertical vein (V) situated along the left side of the transverse aorta (ao) and an innominate vein (In), situated superior to the ao to the right SVC. The left atrium (LA) is extremely small. rpa = right pulmonary artery.

**Figure 12.** (top) Frame from an anteroposterior cineangiogram of a 13-year-old child with mild coarctation of the aorta. Arrow indicates the area of narrowing in the descending aorta, followed by an area of poststenotic dilatation. (bottom) Long-axis suprasternal notch view from the same patient. The ascending and descending aorta (aa and da) is visualized. The black arrow indicates the area of coarctation and poststenotic dilatation.
origin of the brachiocephalic vessels relative to the interruption was clearly seen (fig. 14).

In the long-axis suprasternal notch view in six newborns, the transverse aorta and descending aorta were clearly seen. However, the ascending aorta was extremely small or atretic. The echocardiographic diagnosis of hypoplastic left-heart syndrome was confirmed by aortography in these infants. In the short-axis suprasternal notch view, the transverse aorta was much smaller in diameter than the right pulmonary artery. With anterior tilt of the transducer in the short-axis suprasternal notch plane, the ascending aorta could not be seen clearly.

In one patient admitted for evaluation of a pulsatile mass in the right side of the neck, no structure resembling an aortic arch was seen from the suprasternal notch. When the transducer was placed directly over the pulsatile mass in the same plane as a long-axis suprasternal notch view, an aorta with a narrow, high arch was imaged (fig. 15). Cardiac catheterization demonstrated a persistent cervical aortic arch located on the right side of the neck.

In 72 patients with valvar aortic stenosis, the ascending aorta appeared dilated in the suprasternal notch planes. With anterior tilt of the transducer in the short-axis suprasternal notch plane, we imaged thickened, domed aortic valve leaflets in 51 of these patients.

In 26 patients the aortic arch was not seen in its entirety from the standard long-axis plane in the suprasternal notch. In these cases the transducer was then rotated 30° counterclockwise and tilted slightly toward the patient’s right. If the entire long axis of the aortic arch was visualized in the new transducer position, a diagnosis of right aortic arch was made. The echocardiographic diagnosis of right aortic arch was made and confirmed in 26 patients; however, in 12 patients the aortic arch was not clearly imaged in either location by long-axis suprasternal notch echocardiography. Eight of these patients were later found to have a right aortic arch.

Abnormalities of the Pulmonary Arteries

Infants and children (297 patients) with significant intracardiac left-to-right shunting were noted to have enlarged pulmonary arteries by suprasternal notch echocardiography. Normally the diameter of the right pulmonary artery was equal to or slightly smaller than the diameter of the transverse aorta in the short-axis suprasternal notch view. In patients with significant left-to-right shunting, the diameter of the right pulmonary artery was greater along the entire length.
of the right pulmonary artery. In 62 patients with valvar pulmonic stenosis and poststenotic dilatation, only the area of the main pulmonary artery and its junction with the left pulmonary artery were enlarged; however, the distal right and left pulmonary arteries were usually of normal size (fig. 16).

We examined three patients in whom the entire right pulmonary artery was enlarged far more than was seen in any of the patients with left-to-right intracardiac shunting (fig. 17). At cardiac catheterization these patients were found to have an absent pulmonary valve complex.

In 139 patients with significant right-to-left intracardiac shunting confirmed by cardiac catheterization the pulmonary arteries were small relative to the transverse aorta in the suprasternal notch views (fig. 18). These patients had tetralogy of Fallot, pulmonary atresia with a ventricular septal defect, pulmonary atresia with intact ventricular septum, tricuspid atresia with pulmonic stenosis, critical pulmonic stenosis, or other complex defects with decreased pulmonary blood flow. In several patients we have measured serial pulmonary artery size by suprasternal notch echocardiography to assess the pulmonary blood flow after a palliative shunt procedure.

Discussion

The suprasternal notch provides an echocardiographic window for evaluating the aortic arch, brachiocephalic vessels and the pulmonary arteries. This technique is useful for evaluating coarctation and interruption of the aorta, aortic and pulmonic stenosis, transposition of the great arteries after Mustard's operation, superior vena caval anomalies, and congenital heart disease associated with increased or decreased pulmonary blood flow. Some potential uses of suprasternal notch echocardiography are not illustrated in this report. These views could be used to evaluate left atrial masses, Glenn shunts, or aortic arch anomalies causing vascular rings.

The success of suprasternal notch echocardiography depends largely on the patient's cooperation. Several techniques may be used to make the examination more tolerable for small infants and children. In our laboratory we hang a decorative mobile over the child's head to attract his attention elsewhere while the suprasternal notch examination is performed. In newborn infants the neck may be too short to allow easy access to the suprasternal notch. In these infants hyperextension of the neck may cause the patient to cry or stiffen his entire body, or may be unsafe for the newborn infant who is intubated and mechanically

![Figure 15. Long-axis suprasternal notch view from a 15-year-old patient with a cervical aortic arch located in the right side of the neck. A long, narrow hairpin aortic arch was visualized by placing the transducer in a long-axis plane over the pulsatile aorta high in the right side of the neck. aa = ascending aorta; rpa = right pulmonary artery.](image1)

![Figure 16. Long-axis suprasternal notch view of a patient with valvar pulmonic stenosis. The main pulmonary artery is enlarged because of poststenotic dilatation, but the distal left pulmonary artery (lpa) is of normal size. a = aorta; la = left atrium.](image2)

![Figure 17. Short-axis suprasternal notch view from a patient with absence of the pulmonary valve. The entire right pulmonary artery (RPA) is greatly enlarged. Ao = aorta; LA = left atrium; SVC = superior vena cava.](image3)
ventilated. In such patients, we have often obtained the identical suprasternal notch planes from the area of the manubrium sternum, which is not heavily calcified at this age. Alternatively, the infant may be placed with his entire body supine on a pillow and his head allowed to drop over the edge of the pillow. The suprasternal notch examination can be performed when the infant has relaxed in this position. In some cases we have had the infant's mother place her hand below the child's scapulae and gently lift his back, letting his head fall backward. These techniques help eliminate the problem of poor access to the suprasternal notch in newborn infants.

The success of suprasternal notch echocardiography also depends on the equipment. In order not to frighten or cause pain in young children, a small transducer with minimal mechanical motion is essential. The transducer should have a small circular surface area that fits into the suprasternal notch. Most of the structures examined by suprasternal notch echocardiography are anteriorly situated, so the suprasternal notch examination is best when obtained with a two-dimensional system that has good near-field resolution.

Adequate suprasternal notch examination is not possible in all patients; our failure rate was 7%. Besides the limitations caused by patient cooperation and equipment, variations in the position of the ascending and descending aorta may make the suprasternal notch examination difficult. The suprasternal notch views are especially hard to obtain in patients with a right aortic arch and in patients with l-transposition of the great arteries.

Two-dimensional echocardiography from the suprasternal notch provides a method for evaluating certain structural abnormalities that cannot be seen with other views. This technique should not be used alone in the evaluation of a child with congenital heart disease; rather, it should be used to complement information obtained from standard precordial and subxiphoid views. The application of suprasternal notch echocardiography to the serial assessment of the effects of medical and surgical intervention upon pulmonary artery size should prove extremely useful in the management of children with congenital heart disease.

Acknowledgment

The authors thank William Bunker for preparing the photographs.

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Suprasternal notch echocardiography: a two-dimensional technique for evaluating congenital heart disease.
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Circulation. 1981;63:165-173
doi: 10.1161/01.CIR.63.1.165

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

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