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The Holoacardius: A Correlative Computerized Tomographic, Radiologic, and Ultrasonographic Investigation of a New Case with Review of Literature

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Abstract. A holoacardius from a monozygotic, monochorionic twin pregnancy of 36 weeks is described. Trisomy-18 was diagnosed in the viable female cotwin. Computerized tomographic, radiologic, and ultrasonographic procedures were applied to the acardiac. Its three-vessel umbilical cord was velamentously attached to the single placenta. Grossly malformed and poorly developed craniofacial structures, absence of neck and upper extremities, sirenomelic lower extremity, absence of heart, and development of only a few skeletal elements were prominent features. A review of selected world literature emphasizes the limits of the estimates dealing with the total number of reported cases and the incidence of acardii.

Key words: Acardius, Computerized tomography, Monozygotic twin pregnancy, Ultrasound

INTRODUCTION

A holoacardius (chorioangiopagus parasiticus; acardius) is a rare fetal malformation occurring only in multiple births, most commonly in monozygotic twins, in which one of the twins can be normal, often viable, the other being a mass of skin-covered tissue of varied form and shape, most often devoid of any cardiac tissue, and parasitically anastomosed to the normal circulation of its cotwin. Of all the reported cases no two

have been similar in any respect. Since this anomaly is so rare (only 1 acardius born in every 34,600 births as estimated by Kappelman [16]), it was considered appropriate to report this case presenting the radiological, ultrasonographic and the computerized tomographic (CT) findings, the latter perhaps applied to the investigation of an acardiac specimen for the first time.

CASE REPORT

A 21-year-old white female was admitted to the Louisville General Hospital in labor in August 1978 at an estimated 36 weeks gestational age. There was no history of drug use during pregnancy. The delivery of a viable female twin (A) was followed by still-birth of a malformed twin (B) weighing 400 g and measuring approximately 22.0 x 6.0 x 4.0 cm. Karyotypic analysis of twin A revealed a case of trisomy-18.

The 850 g, 17 x 12.0 x 3.8 cm placenta showed a centrally placed, normally inserted, 26.0 x 0.7 cm, three-vessel umbilical cord, and a peripherally placed, 4.0 x 0.6 cm, three-vessel umbilical cord with a velamentous insertion. The latter cord's vascular distribution was only (10-15%) of the entire placenta and the *two* underlying cotyledons were atrophic.

Dissection by the pathologist revealed no autotransfusion configuration. The chromosomal configuration of twin B (which was received in formalin on 28 August 1978, courtesy of Dr. James D. Rheim, for the embryological collections of the Department of Anatomy, University of Louisville, School of Medicine) could not be determined.

Surface Anatomy

The greatest length of the edematous fetus was 220 mm. The head was covered with brownish hair, likewise the body showed fine lanugo hair. The neck and upper limbs were totally absent. A large trunk tapered to a sirenomelic appendage showing two toes with nails which reached the toe-tips (Fig. 1). The external genitalia and anal opening were absent. The umbilical cord appeared to attach on the trunk, to the left and below the oral structures (Fig. 1).

The facial region was grossly malformed. The right and left eyes, from which membranous sacs protruded, were rudimentary. Except for the indications of eyelids, no other structures seemed to relate to the orbital region. On the forehead between the orbits, a single nostril, over what looked like an intermaxillary segment (Fig. 2), was discernible. Immediately below was a small palate, perforated in the center. The tongue was the largest facial structure and showed a papillated surface. A lower jaw and a wide lower lip were identified. The left upper jaw had some tooth-like structures. On the forehead, a blind opening (Fig. 2) was seen above the nose and between the two orbits. There was no indication of an external ear, although a tiny aperture that was present bilaterally (see Fig. 2), appeared to be far away from where a normal external auditory meatus may have been expected. A similar tiny opening was also present under the right orbit. The dimple on the skin surface (Fig. 1) was bilaterally symmetrical and appeared to be filled with fat nodules.

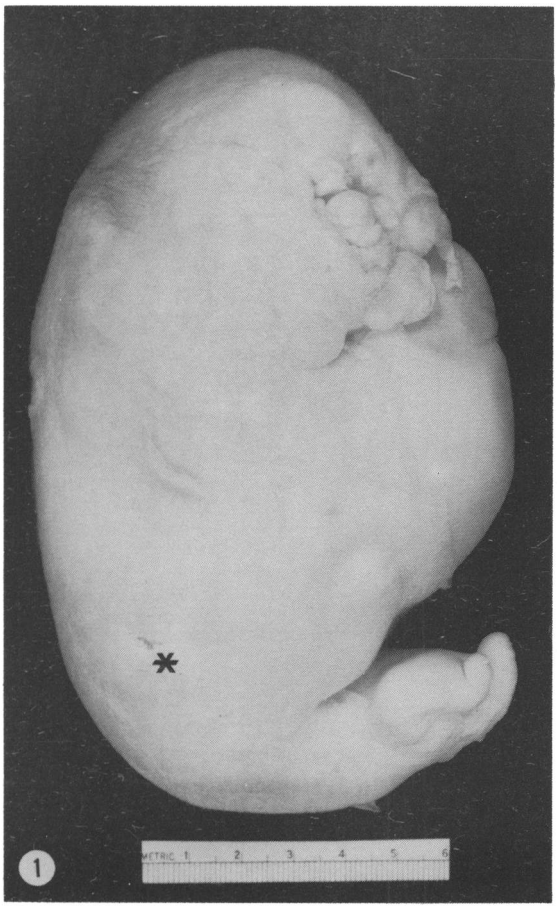

Fig. 1. The holoacardius seen from the right. Note the malformed head, absence of the neck and upper limbs, a large trunk, and the sirenomelic lower limb with two toes, complete with nails. The asterisk (*) denotes the dimple on the surface which is bilaterally symmetrical.

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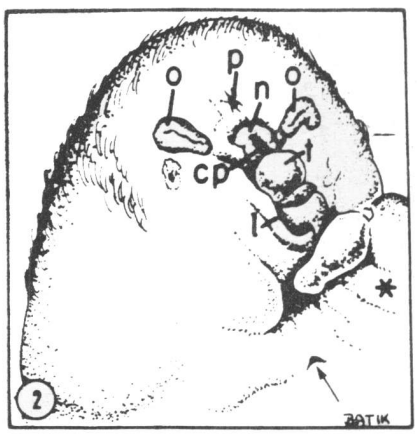

Fig. 2. The facial region of the holoacardius. Note the membranous sacs protruding through what may have been the palpebral fissures; cp, cleft palate; l, lower lip; n, single nostril; o, orbit; p, the blind pit, opening on the forehead, between the orbits; t, grossly enlarged tongue. The asterisk (*) indicates the point of attachment of the umbilical cord under the flap of skin. The palate is immediately superior to the tongue and is not seen clearly. The arrow indicates the tiny aperture (bilateral) which appears to be far away from the site where a normal external auditory meatus may have developed.

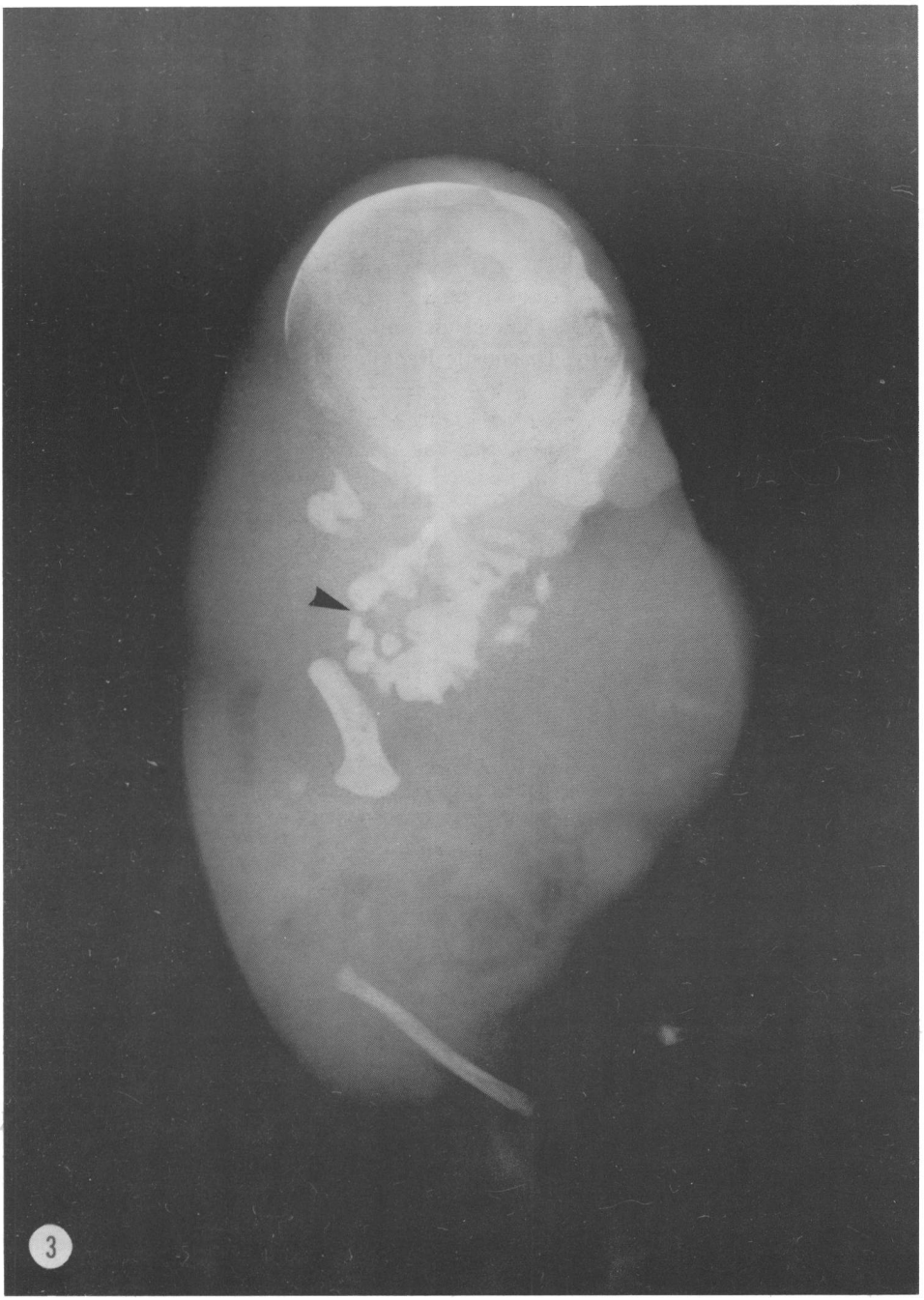

Fig. 3. A radiograph of the holoacardius. Note the well-ossified, thick-boned cranium, a few vertebral elements, a hemipelvis, a single femur, one metatarsal and two phalanges. A spinal dysraphism (spina bifida) is clearly seen and is indicated by the arrowhead. The sternum, ribs, and upper limbs are totally absent, and so are clavicles and scapulae.

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Methods of Analysis

A General Electric 8800 CT Scanner located at the James Graham Brown Cancer Center, University of Louisville, was used to perform computerized tomographic scans on the fetus. Contiguous 5 mm slice thickness and spacing was used from the top of the head to the presumptive thoracic region over a cephalo-caudal distance of 6 cm (Figs. 1,9). Thereafter, the slice thickness was 10 mm. The choice of a 5 mm as opposed to the routine 10 mm slice thickness and spacing used for the rest of the body was to obtain accurate localization and visualization of smaller structures. Figures 4-9 illustrate the internal anatomy of the acardius in transverse CT images through representative body regions in a cranio-caudal sequence.

In addition to the use of the CT scanner, radiographs using a conventional diagnostic X-ray unit located in the Diagnostic Radiology Department of the University of Louisville were also made.

A Diasonics Ultrasound 10 MHz transducer was used to confirm the absence of the heart and to correlate the CT and the radiological findings.

Computerized Tomographic Observations

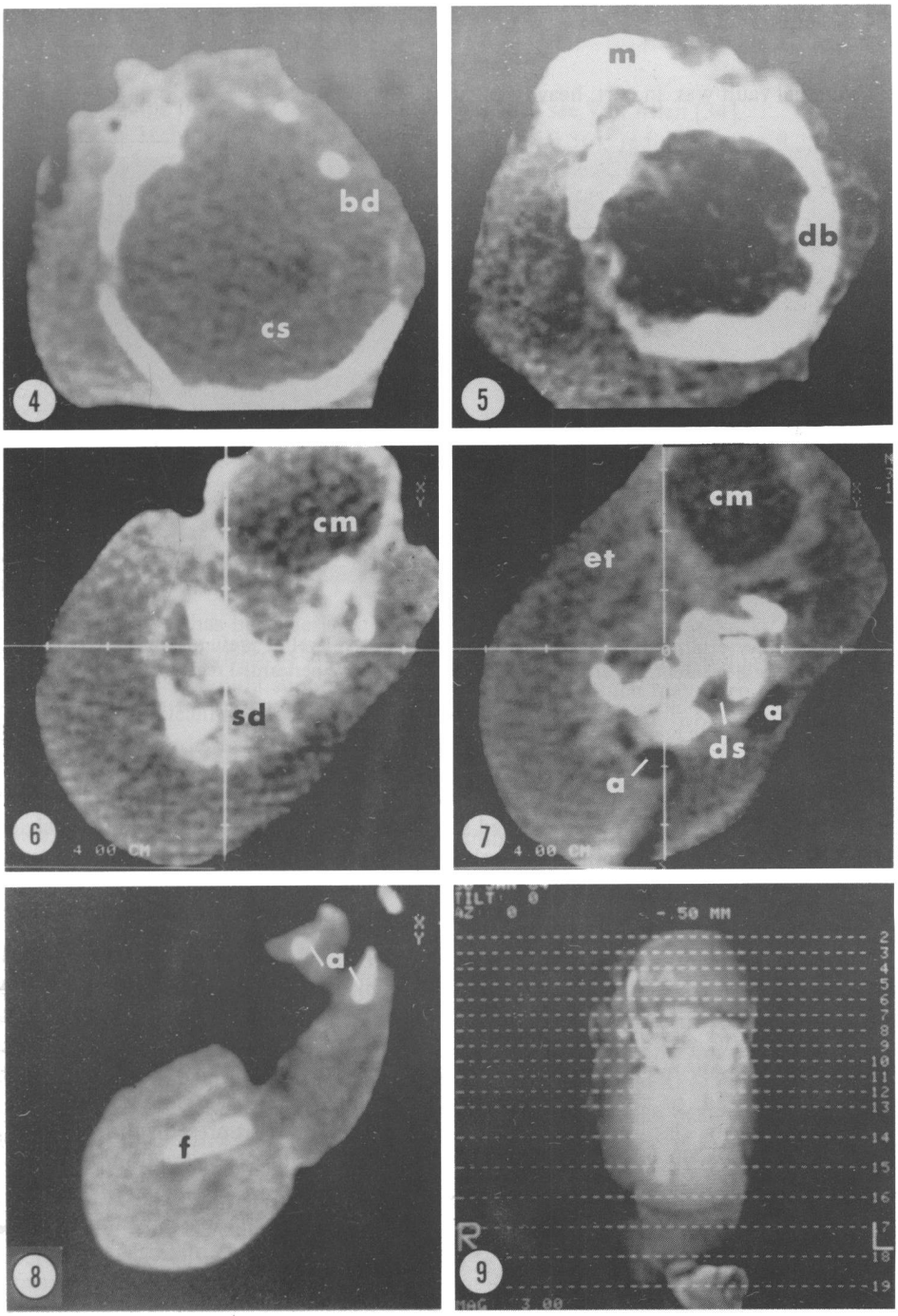
The scans showed a cranial vault with areas of dense and minimal ossification covered by a markedly edematous scalp (Figs. 4,11). No neural tissue was apparent within the fluid-filled skull. There was a fluid collection underneath the skull which appeared to communicate with the intracranial fluid through a bony defect in the skull compatible with meningocele. A portion of maxilla was seen anteriorly (Fig. 5). The dorsal thoracic and lumbar spines were noted to be dysraphic (Figs. 6,7). Images through the lower extremity showed extensive edema surrounding a moderately well ossified femur and two appendages. A fairly well ossified hemipelvis was also identified. Images through a continuous thoraco-abdomino-pelvic cavity failed to reveal lungs, heart, great vessels, diaphragm, or solid abdominopelvic organs. Air-filled tubular structures (Figs. 3,7), which probably represent small and large intestines, were seen.

Radiologic Observations

There was a well-formed neurocranium, though some skull bones were extremely thick while others were poorly ossified. The mandible was imperfectly developed, while the other facial bones (eg, orbital, nasal, maxillary and zygomatic) were poorly developed. The basioccipital region was densely ossified. A few vertebral elements made up the vertebral column; several of these were dysraphic (Figs. 3,6,7). Other skeletal elements present were a hemipelvis, a single femur with well-developed diaphysis and metaphysis, one metatarsal, and two phalanges (Figs. 3,8). The continuous thoraco-abdomino-pelvic cavity was featureless without any apparent development of lungs, heart and great vessels, or diaphragm. No solid viscera (eg, liver, kidneys, spleen) were identified. Numerous air-filled structures (Figs. 3,7) were suggestive of intestinal development. Extensive edema surrounded the entire body.

Ultrasonographic findings

Longitudinal and transverse sonographic images confirmed the presence of marked edema surrounding the cranial vault. The latter contained no discernible neural tissue.



Figs. 4–9. Computerized tomographic (CT) views through selected regions of the holoacardius:
4 – CT scan 6; bd, bony defect in the skull; cs, cystic structure in poorly ossified cranium.
5 – CT scan 8; db, densely ossified base of skull; m, maxilla.
6 – CT scan 11; cm, cystic mass; sd, spinal dysraphism.
7 – CT scan 13; a, air filled structures; cm, cystic mass; ds, dysraphic lumbar spine; et, edematous tissues.
8 – CT scan 19; a, appendages; f, femur.
9 – CT scout view of the fetus.

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The cranial vault was, in part, heavily calcified (Fig. 11).

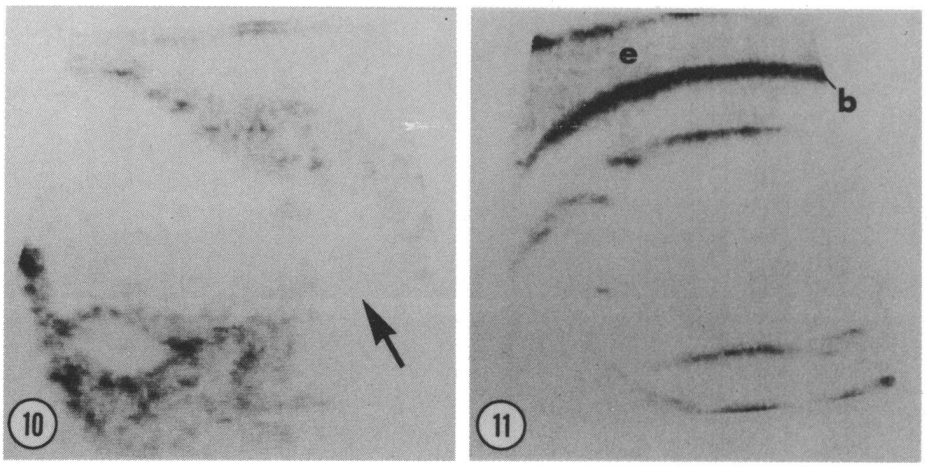

Fig. 10. Transverse ultrasound section of the acardiac at the level of presumptive heart, which in this case is absent. An arrow indicates the presumptive pericardial region.

Fig. 11. Longitudinal ultrasound section through the skull demonstrating the absence of neural tissue and the presence of intracranial fluid. b, bone; e, edema.

Images of the thoraco-abdomino-pelvic cavity did not suggest the presence of heart or major vessels (Fig. 10). No well-defined solid viscera were seen in the abdomino-pelvic cavity. Gas-containing structures, probably representing partial development of bowel, were seen.

DISCUSSION

According to the classification of Napolitani and Schreiber [20], the acardius of this study most closely resembles a case of *Acardius anceps* because of the presence of a rudimentary head, or a *Paracephalus* (headed acardiac, [22]; also see Nishimura and Okamoto [21] for classification of acardia; [7], [26]). The fetus presents the following essential characteristics of a holoacardius: parasitic member of a twin pregnancy in which the other twin was viable; monozygosity, apparently established on the basis of a single, monochorionic placenta (whether the placenta was mono- or diamniotic was not determined at birth; Bieber et al [4] have discussed the role of single chorion in monozygosity; also see Richart and Benirschke [23]); absent neck; a single thoraco-abdomino-pelvic cavity as seen in the CT views and inferred absence of a diaphragm; no indication of a heart on the radiographic, ultrasonographic or CT scans; marked edema; the bilateral skin dimple (Fig. 1) filled with fat nodules corresponding to a similar surface dimple in a previously reported holoacardius (see Figure 1 of Stephens [30]); faulty development of almost every organ system; and velamentous insertion of the cord (considered by Guttmacher and Kohl [13], to be related to monozygotic

twinning leading to acardia in extreme instances; also see Van Allen [34].

Various techniques, including anatomical [18,30,36], radiological [1,9,25], and pathological [18] ones, have been employed in reporting the acardiac condition. Recently, acardiac twins have been diagnosed and managed using ultrasound techniques [8,9,19,24,29,32]. Karyotypic analysis [8,15,23] has also been used in the study of such twins and has been invaluable in establishing the genetic sex as well as in bringing out the chromosomal abnormalities.

Many reports on the acardiac condition have included some review of the literature, principal among these being the reports of Das [7], Simonds and Gowan [28], Gillim and Hendricks [11], Napolitani and Schreiber [20], Wilson [33], Frutiger [10], Bulmer [5], James [14], and Sato et al [26], to cite a few. Therefore, we have refrained from developing a substantial review in this paper.

The holoacardiac condition is very rare, and its etiology still remains unknown. The generally accepted theory for this condition is that, among other predisposing factors, such extreme malformations may also result "from disruption of normal vascular perfusion and development due to an umbilical arterial-to-arterial anastomosis between twins .

The acardiac twin has been designated the perfused twin and the cotwin as the pump twin" [35]. The velamentous attachment of the cord to the two atrophic cotyledons in the present case would support the vascular accident which may have been a contributing factor leading to acardia (also see Averback and Wiglesworth [2]. Multiple etiologies for acardia have been discussed by Kaufman and Walters [17] and Stephens [30]. The present case is similar in external appearance to those reported by Wilson [33] and Scott and Ferguson-Smith [27]. The female sex of the twins in this report lends credence to the data of James [14] regarding slight predominance of females in acardiac twinning.

Incidence

Total reported cases of acardia. After Benedetti's [3] report of the first case of an acardiac fetus, investigators have attempted from time to time to establish the number of acardiacs in the world literature. Table 1 summarizes *some of these* attempts and clearly points out the futility of the undertaking. It quickly became apparent from the data that no report could deal accurately with the total number of the acardiacs. One of the pitfalls of such an ambitious undertaking is that even if the vast world literature is throughly scanned, a wide gap would still remain due to unreported and incompletely recorded cases of acardiacs from numerous developing nations where child births take place at homes even to this day, and where such births abound with superstitions enshrouding these so-called monsters. Frequently, even those authors who claimed careful surveys have failed to cite preexisting reports, thereby failing to establish an accurate count. Recently, Stephens [30] hypothesized that there are "between 400 and 450 cases" of acardiacs born/reported in the world. He gave no basis for this assumption. In his well documented review, James set this figure to 340 by the year 1977; however, by his own admission, even his bibliography was far from being complete. One could not lean too heavily on modern bibliographic sources. (As an example of a chance encounter with an uncited reference, another report on an acardiac by Corner [6] deserves to be recorded here which was discovered for the simple

Table 1. A Sample of Studies Citing the Total Number of Acardiac Births Reported in the World Literature

Number of acardiacs	Year reported	Authors
45	1902	Das
56	1925	Simonds & Gowen
63	1944	Kappelman
151	1960	Napolitani & Schreiber
200	1969	Frutiger[1]
158	1972	Wilson
340	1977	James
165	1980	Lachman et al
160	1983	Dicker et al
400-450	1984	Stephens

[1]Frutiger does not cite Das (1902), and as a result he may have omitted consideration of a substantial number of cases.

reason that it followed a description of an acardiac which was being searched! Corner's citation by later authors remains to be established). From this discussion it follows that there may be a large number of acardiacs born than generally believed.

Frequency of acardia. Even though the generally accepted frequency of one acardius in every 34,600 births is credited to Gillim and Heindricks [11], in reality it is derived from Guttmacher's data cited as "in press" by Kappelman [16], which, however, remains untraceable by us. Kappelman also quotes Guttmacher as having reported that "among 475 plural pregnancies Strassman had two acardii. In 606 twin pregnancies at the Johns Hopkins Hospital we had a single case. Since approximately twenty-five percent of twin pregnancies are monochorionic, the incidence from these two series is approximately once in 100 single chorion specimens". Further, Guttmacher [12] had also established that a set of twins was born in one of every 86.5 births in the United States. Consequently, the frequency of one acardius in 34,600 births no longer remains valid when other reports on the incidence of acardia are considered. In fact, the cumulative incidence that one obtains from four such series (see Table 2) is much lower: approximately one acardius in 48.000, rather than 34,600 births, or one in 143 (0.7%), rather than 100 (1%) monochorionic multiple births. It should be emphasized, however, that the real incidence of the condition is presumably grossly underestimated, as also recently noted by Van Allen et al [35] who cited the highly variable data from the literature on monozygotic twinning occurring in about 1:286 among live births, and in about 1:35 among spontaneous abortions.

Table 2. Incidence of Acardiac Births

Twin sets	Frequency of acardius in: Monozygotic multiple births[a]	Monochorionic multiple births (%)	Total number of births[b]	Reference
1 : 606	1 : 151	0.66	1 : 52,419	Guttmacher as reported by Kappelman (1944)
2 : 475	1 : 60	1.66	1 : 20,544	Strassman (1931) cited in Kappelman (1944)
1 : 422	1 : 105	0.95	1 : 36,481[c]	
		1.00	1 : 34,600[d]	Gillim & Hendricks (1953)
2 : 1055	1 : 131	0.76	1 : 45,629	Napolitani & Schreiber (1960)
			1 : 35,000	Napolitani & Schreiber (1960) as quoted by Simpson et al (1983)
1 : 850	1 : 213	0.47	1 : 73,525	Dicker et al (1983)
1 : 556	1 : 139	0.72	1 : 48,094	Cumulative incidence (this study)

[a]The frequency of acardius in monozygotic multiple births is obtained by the formula, frequency of twin sets /4, assuming monozygotic twinning to account for 1/4 of all twin births. (The recent decline in the dizygotic twinning rate has modified this ratio, which has, however, been retained here, since the established frequency of one acardius in 34,600 births was calculated on the basis of 25 percent of twins being monozygotic).

[b]The frequency of acardius in total number of births is estimated by the formula,

$$\frac{1}{86.5} \times \frac{1}{x}$$

where,

a set of twins occurs once in 86.5 births in the U.S.;

x represents the number of twin sets (both mono-and dizygotic).

[c]This figure, obtained by averaging the data of Guttmacher (1944?), and Strassman (1931), should have been the one reported by Gillim and Hendricks (1953, based on the data quoted in Kappelman, 1944), instead of 1:34,600 which has been widely accepted in the literature.

[d]Estimated by Gillim & Hendricks (see above). Data given in columns 2-4 are calculated in this study.

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