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Perinatal and Short-Term Neonatal Outcomes of Posterior Fossa Anomalies

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Key Words
Posterior fossa · Dandy-Walker · Mega-cisterna magna · Blake's pouch · Congenital anomaly

Abstract
Objective: To describe the perinatal and neonatal outcomes for fetuses with posterior fossa (PF) anomalies – mega-cisterna magna (MCM), persistent Blake's pouch (PBP) or the Dandy-Walker continuum (DWC) – using a new classification. ***Methods:*** 46 cases with PF anomaly diagnosed on ultrasound (US) between 16 and 28 weeks' gestation were included. The images were reviewed and classified as one of the following: MCM, PBP or DWC. Outcomes were obtained from patient records. ***Results:*** 30 cases with DWC, 6 with MCM, and 10 with PBP were identified. Associated anomalies were present in all groups, but more frequent in DWC. Agenesis of the corpus callosum and ventriculomegaly were more common in DWC than in MCM or PBP. Only fetuses with DWC were found to have chromosomal abnormalities. Perinatal outcomes differed significantly, with terminations of pregnancy more frequent in DWC. In the immediate postnatal period, infants with DWC had worse outcomes than those with MCM and PBP. Across all groups, those with associated anomalies had worse outcomes than those with an isolated PF anomaly. ***Conclusion:*** Infants antenatally diagnosed with DWC had worse perinatal and short-term neonatal outcomes than those with MCM or PBP. Those with associated anomalies had uniformly poorer outcomes than those with isolated anomalies.

Introduction

Central nervous system (CNS) anomalies are the second most common group of congenital anomalies diagnosed prenatally. Of terminations of pregnancy (TOP) in the Australian state of Victoria (2007), 52% were a result of these fetal anomalies [1]. Therefore, accurate diagnosis and prognosis are important when counselling parents.

Acknowledging the chaotic nomenclature of these anomalies, we will discuss the perinatal and short-term neonatal outcomes of anomalies presenting with increased pericerebellar fluid, as classified in figure 1, and propose a simple and pragmatic classification scheme.

The Dandy-Walker continuum (DWC) of anomalies includes the spectrum of vermian agenesis combined with cystic dilatation of the fourth ventricle, which enlarges into and thus obliterates the cisterna magna (CM) space. Traditionally this includes the 'Dandy-Walker malformation' (DWM) at one end of the spectrum and the 'Dandy-Walker variant' (DWV) or 'inferior vermian hypoplasia' at the mild end, however the literature is confusing with regard to this point.

The mega-cisterna magna (MCM) involves enlargement of the CM with no vermian abnormality. Similarly, the persistent Blake's pouch (PBP) involves non-pathological rotation of the vermis due to enlargement of the remnant of Blake's pouch.

Little is known about the perinatal short-term outcomes for DWC, MCM and PBP fetuses. Anomalies of the posterior fossa (PF) are significantly associated with

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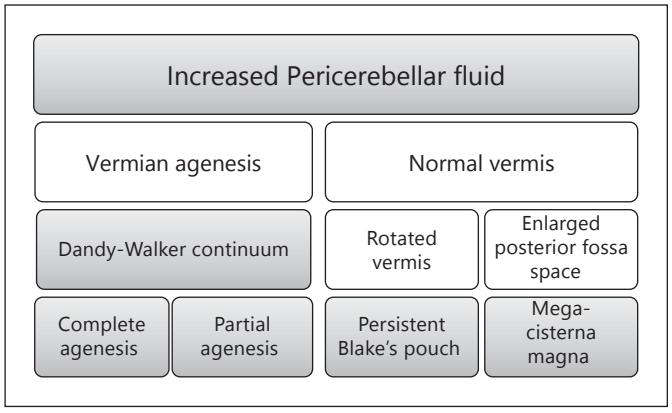

Fig. 1. Classification of PF anomalies.

other intra- and extracranial anomalies, particularly ventriculomegaly, agenesis of the corpus callosum, and cardiac anomalies [2–4]. Many studies recognise that it is the presence of associated anomalies in these fetuses, rather than the severity of the malformation, which correlates with a worse perinatal outcome [2, 5–13]. As a result, screening for other anomalies is advocated when a diagnosis of a PF anomaly is made [3, 14–16].

Some authors also report a high incidence of abnormal karyotypes amongst these infants [4, 8, 12] – 17.6% of combined DWM and DWV fetuses by Has et al. [4] and 29% of MCM fetuses by Ulm et al. [12]. However, Kölble et al. [14] found normal karyotypes in all 7 DWM cases tested. Several studies support the theory that isolated MCM malformation has a favourable prognosis of normal developmental outcome [13, 17, 18], and isolated DWC fetuses can expect a good prognosis in up to 67% [13]. Knowledge of the long-term outcome on PBP is limited to 6 case studies of adults diagnosed after presenting with hydrocephaly [19].

This study aims to provide clinicians with a greater understanding of the perinatal and short-term neonatal outcomes for infants with PF anomalies presenting with increased pericerebellar fluid, aided by the use of a simplified classification scheme and thus improve information available for counselling parents.

Methods

This is a retrospective cross-sectional study of fetal cases with PF anomalies seen at The Royal Women's Hospital (RWH) Fetal Medicine Unit between August 2003 and June 2010. This tertiary centre is the major referral centre for fetal anomalies in Victoria. The average number of births at RWH during this study period was 6,500 annually. The cases were selected from the Picture Archiving and Communication System (PACS) database containing ultrasound scan (US) reports and images of all fetal scans performed at RWH from August 2003 to present. Cases were diagnosed on routine anomaly scan at RWH, or were referred to RWH for a second opinion after an initial suspicious routine anomaly scan.

A search was conducted to identify cases based on the presence of the following key terms in the US report: DWM, DWV, MCM, PBP, vermian agenesis or hypoplasia, PF cyst or pericerebellar fluid collection. 74 individual cases were identified in this manner. The first US examination to diagnose this anomaly should have occurred between 16 and 27 + 6 weeks of gestation inclusive, in order to prevent misdiagnosing early vermian development as pathological, eliminating 11 cases whose US were outside this range. 17 cases with coexisting or subsequently diagnosed neural tube defects or global brain anomalies (e.g. lobar holoprosencephaly) were further excluded. This provided a total pool of 46 cases for this study.

The original reported diagnosis made at RWH was used to include cases in the study. Subsequently, the 46 cases were independently reassessed and reclassified by two of the authors using the criteria below. They were then reviewed by two senior imaging specialists to confirm the diagnosis using these criteria. Where discrepancies were found between the original and the reconfirmed diagnoses, the latter was used for the diagnostic classification in this study. Although not all US had ideal imaging planes available, the cases were distributed into the categories using the best information available in PACS.

The criteria for diagnosis of the PF anomalies were based on current best practice definitions (fig. 2). A diagnosis of DWC followed evidence of absence (complete or partial) or hypoplasia of the vermis on US, with or without cerebellar hypoplasia, and/or open communication between the fourth ventricle and CM space. These cases were then subdivided into those with partial vermian agenesis (DWC-PVA) and those with complete vermian agenesis (DWC-CVA). When none of the above findings were present, but the CM measured >10 mm, the case was classified as MCM (we note that a large CM may be secondary to global cerebellar hypoplasia rather than an enlarged CM per se). PBP was diagnosed on visualisation of a normal cerebellum and vermis that was rotated superiorly due to the presence of a PBP. These cases include those with pseudo 'inferior vermian agenesis'.

Images and reports from RWH US Department PACS were reviewed. 17 fetuses went on to have further magnetic resonance imaging (MRI) to evaluate the PF, in concordance with emerging best clinical practice, however for this study, only US images were used to categorise the cases. Maternal and pregnancy outcome data were collected from medical records for 39 of the cases, as 7 were lost to follow-up. Of these pregnancies, 22 were terminated which allowed 17 to be analysed for neonatal outcomes. Where available, routine neonatal data was collected for infants born at RWH, however some cases had incomplete follow-up due to delivery outside RWH. Data was stored using a dedicated database. Statistical analysis was performed with Student's t test and multivariate analysis where $p < 0.05$ was considered significant. Categorical data was compared using one-way tables and Pearson's χ^2 values. Continuous variables were analysed using a combination of one-way tables (to compare all three groups simultaneously) and two-sample t tests (to compare two groups at a time) with variances analysed using Bartlett's tests for equal variances.

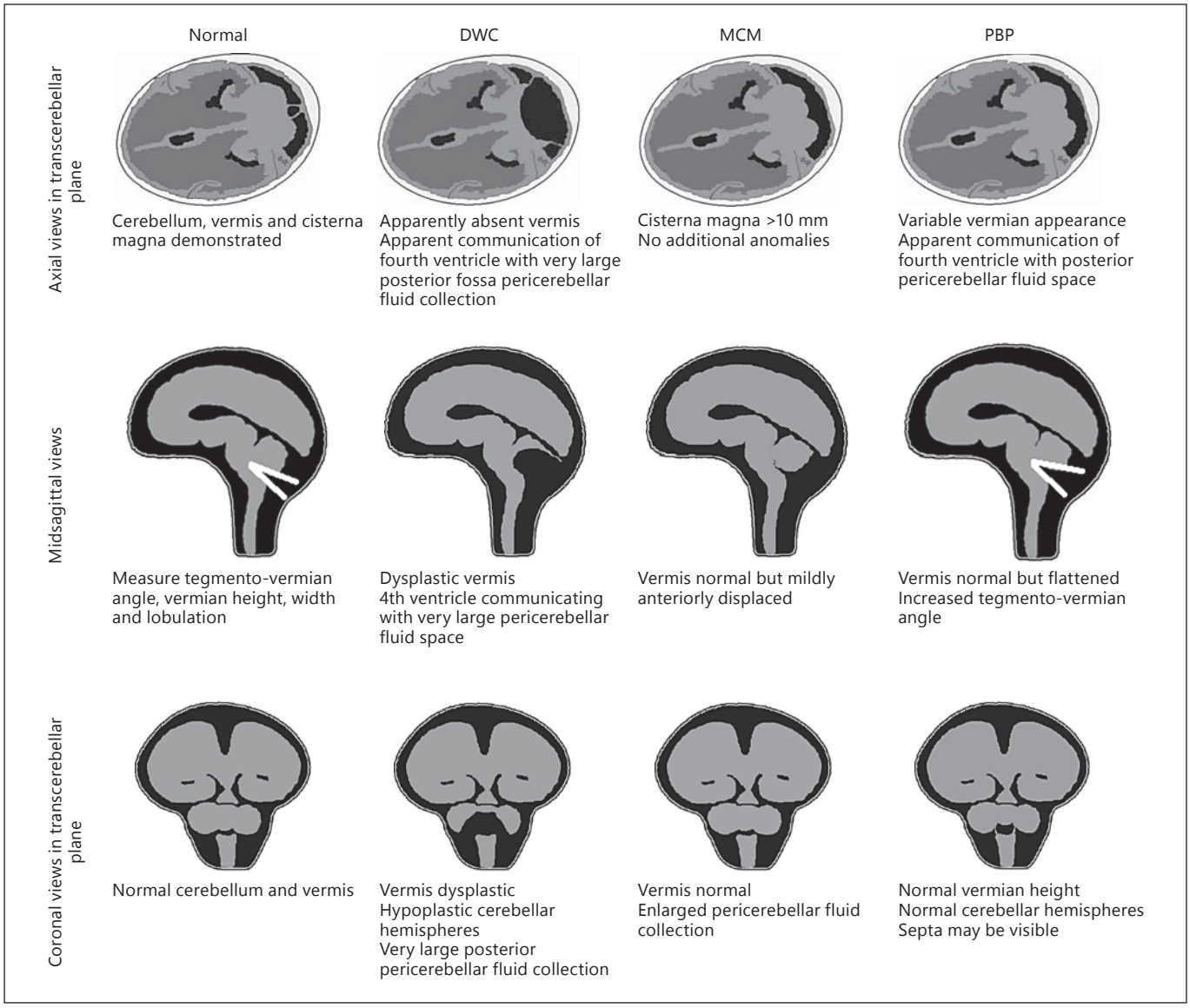

Fig. 2. PF anomalies as seen on multiplanar US imaging (schematic).

Results

This study identified 46 confirmed cases diagnosed with a PF anomaly on US; 30 were classified as DWC, 10 as PBP, and 6 as MCM. Of the 30 DWC cases, 20 had DWC-PVA and 10 cases had DWC-CVA. 45 of the cases were singleton pregnancies, 1 was a dichorionic-diamniotic twin whose co-twin was normal.

Of the 46 confirmed cases, 2 fetuses had a revision of their original US diagnosis. One case was initially diagnosed with MCM, with a revised diagnosis of PBP, whilst the other case was initially classified as PBP but due to the recognised vermian dysplasia, was reclassified as DWC. Tables 1 and 2 present the demographic results and morphometric results of US images. No significant differences were found between the groups for place of first US diagnosis, rates of consanguinity or gender of the fetus. However, MCM fetuses were diagnosed at significantly later gestational ages than DWC or PBP fetuses, and the maternal age was younger for these pregnancies than for DWC or PBP pregnancies. Also, no significant differences were found between the groups for fetal head circumference measurements, or transcerebellar diameter centile, although PBP fetuses were significantly more likely

Table 1. Demographic characteristics in each diagnostic group

Result	DWC, n (%)	MCM, n (%)	PBP, n (%)
Place of first diagnosis			
RWH	13 (43)	3 (50)	4 (40)
Other	17 (57)	3 (50)	6 (60)
Consanguinity	2 (7)	0 (0)	1 (10)
Gender[a]			
Male	18 (67)	4 (100)	7 (78)
Female	9 (33)	0 (0)	2 (22)
Maternal age at first RWH diagnosis, years, mean ± SD	29.5±5.02	24.8±3.97[b, *]	30.4±4.62
Gestational age of the fetus at first diagnosis, weeks, mean ± SD	19.7±3.18	22.6±4.12[c, *]	19.8±1.70

* Statistically significant value.

[a] The gender of the fetus was not determined in 6 cases.

[b] p value 0.0358 when comparing maternal age of MCM and DWC fetuses, p value 0.0254 when comparing maternal age of MCM and PBP fetuses.

[c] p value 0.0158 when comparing gestational age of MCM and DWC fetuses at diagnosis, p value 0.0195 when comparing gestational age of MCM and PBP fetuses at diagnosis.

Table 2. Comparison of morphometric results of US images

Result	DWC	MCM	PBP	Significance
TCD centile				NS
Abnormal (<5%)	3	0	0	
Normal (5–95%)	19	6	8	
Abnormal (>95%)	2	0	1	
CM centile				
Normal (5–95%)	5	0	5	p = 0.000*
Abnormal (>95%)	18	6	4	p = 0.000**
Fetal HC, mm, mean ± SD	183.0±37.0	202.7±47.5	188.2±19.9	NS

NS = Not significant. * MCM compared with PBP. ** MCM compared with DWC.

to have a normal CM centile than their peers. Note that not all data were available for every case, hence the total does not always add up to 46.

26 (57%) anomalies were first diagnosed external to the RWH and then referred to our tertiary centre for confirmation of the anomaly, and management of the pregnancy. 30 US were undertaken for the indication of 'fetal anomaly', one of which was also indicated for a familial history of hydrocephaly. One US was performed for 'reduced fetal movements', 2 for 'increased risk of trisomy 21' due to maternal age, and the remaining 13 were routine anomaly scans. On reviewing the saved US images, 36 fetuses had axial views in the transcerebellar plane identifying the anomaly, 14 had coronal views in the transcerebellar plane, and 9 had midsagittal images. No fetuses were diagnosed using midsagittal images alone, 2 fetuses were diagnosed using coronal images only and 18 cases were diagnosed using axial images only.

The presence of other anomalies at the time of the first US was also recorded. 32 of the 46 cases (70%) had at least one additional anomaly: 77% of DWC, 50% of MCM, and 60% of PBP. 65% (13 of 20) of fetuses with DWC-PVA had associated anomalies compared with 100% (10 of 10) of those with DWC-CVA. This finding is statistically significant. 50% (5 of 10) of fetuses with DWC-CVA also have ACC, which is similar to the 40% (8 of 20) of DWC-PVA cases with ACC. Table 3 presents our findings on the associated anomalies, karyotypic and serological abnormalities of the fetuses. 36 fetuses were tested for karyotypic abnormalities (2 MCM, 6 PBP and 28 DWC) result-

Table 3. Comparison of associated findings

Result	DWC, n (%)	MCM, n (%)	PBP, n (%)	Significance
Presence of associated anomalies				NS
No	7 (23)	3 (50)	4 (40)	
Yes	23 (77)	3 (50)	6 (60)	
Anomalies by system (DWC: n = 30) (MCM: n = 6) (PBP: n = 10)				p = 0.020*
CNS	19	2	1	
Cardiac	9	1	1	
Gastrointestinal	4	0	0	
Musculoskeletal	9	0	1	
Urogenital	4	1	1	
Other	7	0	5	
CNS anomalies				NS
VM (n = 13)	10	2	1	
ACC (n = 12)	11	1	0	
Hydrocephaly	1	0	0	
Choroid plexus cyst	1	0	0	
Other	5	0	0	
Abnormal karyotype (n = 36)	9	0	0	NS
Abnormal serology (n = 33)	0	1	0	NS

NS = Not significant. * DWC fetuses have the largest proportion of associated CNS anomalies both by system and when compared to MCM and PBP groups.

Table 4. Immediate pregnancy outcomes by diagnostic group[a, b]

	TOP, n (%)		NND, n (%)		Live, n (%)	
	isolated	non-isolated	isolated	non-isolated	isolated	non-isolated
DWC-PVA (n = 17)	3 (18)	8 (47)	–	3 (18)	2 (12)	1 (6)
DWC-CVA (n = 10)	–	8 (80)	–	1 (10)	–	1 (10)
MCM (n = 4)	–	1 (25)	–	–	1 (25)	2 (50)
PBP (n = 8)	1 (13)	1 (13)	–	–	2 (25)	4 (50)
Total (n = 39)	4 (10)	18 (46)	–	4 (10)	5 (13)	8 (21)

[a] In Victoria, TOP for complex fetal anomalies became available, even after 24 weeks' gestation, in 2009. Hence, parental decision to terminate is not always directly related to the predicted prognosis. Especially in the earlier years, some parents chose to terminate in view of the uncertainty, as termination was not always possible at a later stage.

[b] Only 39 cases provided immediate pregnancy outcomes as 7 cases were lost to follow-up.

ing in 9 abnormal results amongst DWC fetuses (7 amongst DWC-PVA and 2 in DWC-CVA). 33 pregnancies were tested for abnormal serology (toxoplasmosis, rubella, cytomegalovirus and hepatitis) (5 PBP, 7 DWC and 1 MCM). Only 1 fetus with MCM tested positive for cytomegalovirus.

Pregnancy outcome data was available for 39 cases due to some infants being delivered outside RWH (7 cases lost to follow-up). Table 4 compares the immediate pregnancy outcome for the fetuses. 22 (56%) underwent TOP, 17 infants were born live and 4 of these infants suffered neonatal death (NND); 3 had DWC-PVA and 1 had DWC-CVA. 70% of DWC fetuses were terminated (11 with DWC-PVA and 8 with DWC-CVA) compared to only 25% of both MCM and PBP fetuses. Interestingly, 50% of live-born infants with CVA and PVA suffered NND.

The type of delivery does not differ significantly between the four groups. However, 4 (57%) of the 7 LUSCS

are emergency deliveries. Rate of admission to neonatal intensive and special care units (NISC) is not statistically significant between the three groups, however those needing admission were expected to have poor outcome due to the presence of multiple other anomalies.

The neonatal outcome for the live-born fetuses can be seen in table 5 and their demographic data is summarised in table 6. Follow-up extended from birth to 28 days, during which time all infants underwent a minimum neonatal cranial US and routine paediatric examination, with MRI being performed according to the results of this initial assessment. Although there was no significant difference between gestational age at birth, weight at birth, type of delivery or admission to neonatal intensive care units (NICU), DWC infants had poorer outcomes in the immediate neonatal period – such as requiring NICU, or suffering NND – than their peers. Also, infants with significant other associated anomalies had poorer outcomes than their peers with isolated PF anomalies – such as suffering complications during hospitalisations, requiring NICU or suffering NND. Routine neonatal follow-up was not performed at RWH and no infants represented to RWH within the neonatal period for management of the PF anomaly. Infants requiring further investigation beyond the neonatal period were referred to the Royal Children's Hospital or other major regional paediatric service.

Discussion

In this study, we identified the variation in perinatal and short-term neonatal outcome of PF anomalies depended on the severity of the anomaly, as well the presence of associated anomalies. In particular, perinatal outcome of infants with DWC is poor, with 70% undergoing TOP, and 50% of continuing pregnancies suffering NND. Across MCM and DWC groups, infants with associated anomalies had a worse perinatal and neonatal outcome compared to their isolated peers. However, this was not the case for PBP fetuses as terminations amongst isolated and non-isolated cases were equal, which may be a result of paucity of data in aiding prognostic counselling for these cases.

Mothers of MCM fetuses were found to be younger than those of DWC ($p = 0.0358$) and PBP ($p = 0.0254$) fetuses, the significance of which is unclear but may be cause to encourage younger mothers to have perinatal imaging. Several studies report that MCM is diagnosed at a later gestational age than DWC, and our study population confirms this difference (22.6 compared to 19.7 weeks) [3, 6, 16], a finding which could be due to the slow development of MCM compared to DWC. Other studies however suggest a later gestational age at first diagnosis of the DWC [4, 14].

Although the literature suggests an even distribution between gender for the DWC [13, 20–23], or female predominance [4, 5, 14, 24, 25], this study identified a greater proportion of males across all groups, as seen in only some studies on the DWC [6] and MCM [6, 13].

Pilu et al. [26] previously recommended that sonographers should not rely on the transcerebellar diameter to definitively differentiate between PF anomalies, and our study confirms that there is no significant difference in this measurement between the three groups. However, a normal CM centile may be useful in differentiating PBP from MCM or DWC, which typically record abnormal CM measurements.

The literature reports that 54–83% of DWC and 63–85% of MCM are associated with other anomalies [2, 3, 5, 6, 8, 12, 13, 16], and our study confirms this association with additional anomalies across all groups. Therefore, a high index of suspicion should be maintained when a PF anomaly is found, and a detailed anatomy scan should be performed in the likelihood that the anomaly is not isolated. The concordance with associated anomalies, particularly of the CNS (especially ventriculomegaly and agenesis of the corpus callosum) amongst DWC fetuses suggests a global developmental abnormality as the cause of this malformation, and also in the development of MCM and PBP, although to a lesser extent [2–4, 8, 12, 13, 16, 27]. In this study, 37% of DWC fetuses had ACC, which is the highest reported proportion thus far [2, 4, 14, 16]. This difference could result from an increased vigilance in identifying midline brain anomalies when a PF anomaly is found on US. Also, the significantly higher rates of non-isolated DWC with CVA, compared to those with PVA ($p = 0.033$) should prompt sonographers to be extra cautious in diagnosing isolated DWC-CVA, as it is extremely unlikely. This confers a worse outcome for DWC-CVA cases.

Contrary to the literature, we were unable to confirm the presence of karyotypic abnormalities in cases of MCM and PBP, and found the proportion of abnormal karyotype in DWC fetuses to be not significantly different to the other groups [2–4, 6, 8, 12, 14, 16]. However, MCM could be linked to congenital cytomegalovirus infection as previously reported, as 1 case of MCM was found to be positive on polymerase chain reaction testing [13].

The current literature suggests that 33–81% of DWC and 8–26% of MCM undergo TOP as a result of prognos-

Table 5. Neonatal outcome of live-born fetuses by diagnostic group

	Karyotype	Apgars at 1 and 5 min	Min to breathing	Resuscitation	NISC days	Follow-up notes
DWC-PVA						
No	46XY	9, 9	0	none		MRI on day 17 showed: mildly enlarged PF with torcular elevation, hypoplastic and superiorly rotated inferior vermis, enlarged 4th ventricle opening posteriorly into a large PF 4-cm cyst.
No	46XY	8, 8	<1	none		Paediatric cranial US on day 2 showed: enlarged CM, 4th ventricle not dilated, normal foramen magendie and normal cerebellum. MRI on day 12 with IV contrast showed: PF abnormally horizontally elongated in shape with retrocerebellar CSF collection that does not elevate the torcular/tentorium. Normal cerebellum, mild inferior vermian hypoplasia, 4th ventricle that communicates with the CSF collection.
Yes	46XY	9, 9	<1	none		Paediatric US on day 1 showed: normal PF. Paediatric US on day 9 showed: normal cerebellum, large 4th ventricle and foramen magendie with hypoplastic inferior vermis but normal superior vermis.
Yes	46XY, der(4) t(4;13) (p15.32;q32)	7, 9	<1	oxygen	NICU 1 SCN 2	NICU admission due to chromosomal abnormality. Discharged to HITH, NND age 5 days.
Yes	99kb micro-deletion of 2q23.1	1, 3	99	bag and mask IPPR suction		NND – data incomplete.
Yes	46XY	5, 8	<1	IPPR via ET	NICU 3	NICU admission due to severe congenital anomalies. Paediatric cranial US on day 1 showed: absent bone in cranial fossa, large 4th ventricle with large CM and normal cerebellum. NND on day 5. Hospital stay complicated by pneumothorax, infection, thrombocytopaenia, neutropenia, seizures. Dysmorphic infant. Post-mortem identifies inferior vermian hypoplasia.
DWC -CVA						
Yes	46XX	8, 9	<1	none	SCN 9	NICU admission due to thrombocytopaenia. Paediatric cranial US on day 6 showed: cyst in PF, absent and elevated vermis. MRI on day 11 showed: enlargement of the PF due to a cyst communicating with the 4th ventricle with hypoplasia of the cerebellum. Discharged from SCN to HITH. Hospital stay complicated by sepsis and thrombocytopaenia.
Yes	46XX, der(8) t(7;8) (p11.2;p23)	2, 6	2	bag and mask IPPR	NICU 3 SCN 3	NICU admission due to chromosomal abnormality and tetralogy of Fallot malformation. Paediatric cranial US on day 1 showed: enlarged CM with hypoplastic inferior vermis, large foramen magendie and dilated 4th ventricle. X-ray on day 5 showed normal cranium. NND on day 7. Dysmorphic infant. Hospital stay complicated by infection and hypoglycaemia.
MCM						
Yes	not done	9, 10	1	none		Paediatric cranial US on day 2 showed: abnormal cerebrum. MRI on day 3 showed: normal PF and 4th ventricle.
Yes	46XY	8, 9	<1	none		Paediatric cranial US on day 2 showed: left cerebellar hypoplasia with extensive cerebral and ventricular abnormalities.
PBP						
No	not done					Delivered outside RWH. Paediatric cranial US (day unknown) showed near normal PF.
No	not done	9, 9	<1	none		Data incomplete.
Yes	46XX	3, 3	98	suction oxygen IPPR via ET	NICU 1	NICU admission due to congenital anomalies. Paediatric cranial US on day 1 showed: normal cerebrum and cerebellum but vermis not well assessed. MRI (day unknown) showed: deficiency of inferior vermis. Paediatric cranial US on day 9 showed: normal cerebrum and cerebellum and PF.

Table 5. (continued)

	Karyotype	Apgars at 1 and 5 min	Min to breathing	Resuscitation	NISC days	Follow-up notes
Yes	46XY	7, 9		suction bag and mask IPPR	SCN 21	NICU admission due to low tone at birth. 3 weeks in a regional hospital SCN for low tone and slow to establish feeds. MRI (day unknown) showed: normal anatomy but prominent 4th ventricle.
Yes	46XY	9, 10	<1	none		MRI on day 4 showed: PF cyst with increased tegmento-vermian angle at 28° with vermian rotation. The vermis is normally formed but there is failure of the 4th ventricle to close. Diagnosis of PBP.
Yes	not done	9, 9	<1	oxygen	SCN 9	NICU admission due to prematurity, IUGR and low birth weight. 9 days in NICU then sent to a local hospital and spent 10 days in SCN for prematurity. Paediatric cranial US on day 5 showed: hypoplasia of the inferior vermis, increased CM, dilated foramen magendie leading into the 4th ventricle. MRI on day 6 showed: hypoplastic inferior vermis and widening of foramen of magendie. Neonatal course complicated by jaundice, infection and hypoglycaemia.

AA = Associated anomalies; NISC = neonatal intensive or special care; NICU = neonatal intensive care unit; SCN = special care nursery; HITH = hospital in the home.

Table 6. Comparison of demographic data for live-born infants

Result	DWC	MCM	PBP
Gestational age at birth, weeks			
Number	8	3	6
Mean ± SD	38.5±1.69	38.7±0.57	37.3±2.50
Weight at birth, g			
Number	8	3	5
Mean ± SD	2,769±823	3,359±541	2,711±974
Type of delivery			
LUSCS	3	0	4
NVD	5	2	2
Vacuum	0	1	0
Neonatal intensive and special care units	4 of 8	0 of 3	3 of 5

Of the 17 live-born infants, weight at birth and admission to neonatal intensive or special care was not available for 1 of the 2 infants delivered outside RWH.

tic counselling, a result that is similar to our own findings. In Victoria, TOP for complex fetal anomalies became available, even after 24 weeks gestation, in 2009. Thus, parental decision to terminate is not always directly related to the predicted prognosis in this series. Particularly in the earlier years, some parents chose to terminate in view of the uncertainty, as termination was not always possible at a later stage. However, it is understandable that the poor long-term neurological outcome of DWC results in higher rates of termination in this group than in MCM or PBP fetuses. The poor short-term neonatal outcome for DWC infants in this study (50% of continuing pregnancies resulted in NND) was attributed to the presence of associated anomalies. Like Salihu et al. [28], this leads us to recommend that even in the presence of a severe PF anomaly such as DWC, the presence of additional anomalies confers a very poor short-term neonatal outcome, in addition to the poor long-term neurological outcome. The generous 74–77% survival of MCM infants compared to 10–53% of DWC infants is a strong factor in the low rates of termination found amongst this group. Given that 2 of the 3 infants with non-isolated MCM survived the neonatal period, this suggests that associated anomalies in this group has little impact in the immediate perinatal outcome, but nevertheless impacts on the short-term neonatal course. Otherwise, isolated MCM can be expected to have a good neonatal outcome [6, 8, 13, 17, 18]. Isolated PBP anomalies can expect to have a good short-term neonatal outcome, and follow-up imaging is useful in demonstrating regression or persistence of the PBP in the neonate, as well as identifying the presence of vermian dysplasia, which would justify reclassification of the diagnosis to DWC. These infants have a poorer prognosis than isolated or non-isolated PBP infants.

In general, infants with non-isolated malformations have significantly poorer neonatal course – a finding consistent with results from other studies [2, 5, 9, 10, 29, 30] – as do those infants diagnosed with DWC compared to

their peers. Other studies have already identified that the degree of vermian agenesis in DWC cases corresponds to a worse long-term neonatal outcome as determined by abnormal intelligence quotient (<70) on formal testing [5, 9, 21, 30], however the degree of vermian agenesis has no significant effect on the short-term neonatal outcome of DWC fetuses.

Given that this study was a retrospective cross-sectional study, we were limited by the presence of incomplete data within saved US images, maternal and fetal history. Also, given that neonatal follow-up is not routinely conducted at the RWH, and that most neonates represent to the Royal Children's Hospital beyond the neonatal period, we were unable to gather complete information about the entire 28-day period for every neonate.

A strength of this study is the use of a simple classification scheme that is based upon current knowledge, and comparing perinatal and short-term neonatal data on DWC, MCM and PBP fetuses. This is the first study reporting data on all three PF anomalies with such a sample size.

Conclusion

Anomalies of the PF, presenting with increased pericerebellar fluid, have little influence on the neonatal outcome of infants when found in isolation. However, if associated anomalies are present, these infants have a poorer prognosis; hence the importance of detailed antenatal US examinations.

Fetuses with MCM appear to be diagnosed at a later gestational age compared to those with PBP or DWC. This study identified male predominance across all the PF anomalies. There were low rates of consanguinity across all groups. Cases with PBP may be distinguished by the normal CM relative to the other groups, whilst measurement of the transcerebellar diameter (TCD) may not be useful in differentiating between these three PF anomalies.

DWC cases have a greater incidence of associated anomalies than do MCM or PBP cases. ACC and VM are common associated anomalies. DWC fetuses are far less likely to have isolated PF malformations, which confers a worse prognosis for them relative to MCM or PBP groups. Within the DWC, fetuses with CVA are more likely to have associated anomalies than cases of PVA, coinciding with a poorer prognosis.

Karyotypic abnormalities were not statistically significant between the groups. Congenital CMV infection was the only positive serology result identified in a fetus with MCM, conferring a poor prognosis for this fetus. DWC cases appear not to be linked to congenital infections.

The perinatal outcome was significantly different between the groups, and a higher proportion of DWC pregnancies underwent termination, probably due to the predicted severity of perinatal outcome. Of those fetuses born live, gestational age and weight at birth were not significantly different, neither was the type of delivery for the infant. However, infants with associated anomalies were significantly more likely to require admission to NISC compared to those with isolated PF malformations, and this is reflected in their poorer outcomes.

Overall, infants with isolated PF malformations have better perinatal and short-term neonatal outcome than those with associated anomalies. Fetuses with a diagnosis of MCM or PBP have better short-term neonatal outcomes than those with DWC. The DWC is a spectrum of malformation that extends from complete to PVA, with poorer prognosis if complete.

Further research is necessary to validate these results for the three groups, with particular attention to careful assessment of the PF in multiple planes. Clinicians must be made aware of the importance of making an accurate first diagnosis using consistent criterion, with focus on the presence or absence of associated anomalies in the fetus. This is to assist prospective parents in making an informed decision about the pregnancy.

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