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A synoptic framework and future directions for placental pathology reporting

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ABSTRACT

Placental pathology is a key modality for determining placental health during pregnancy, especially in the event of adverse pregnancy outcomes. However, issues with standardization in placental diagnosis, reporting practices and clinical translation prevent this modality from being used to its full potential. This article will highlight these standardization issues and summarize ongoing work in this field to overcome them. Additionally, we propose a synoptic reporting framework for placental pathology based on current consensus guidelines, aimed at enhancing the comprehensiveness and quality of reporting placental findings. We believe this approach will improve our understanding of the placenta in adverse pregnancy outcomes and, importantly, offer the opportunity to increase knowledge translation to key stakeholder groups including patients.

1. Introduction: the placenta is central to obstetric health

A healthy placenta is vital for a healthy pregnancy, essential for fetal survival and mediating maternal adaptation to pregnancy [1]. Abnormal development and function of the placenta can put mother and fetus at risk for a number of placenta-mediated complications, including preeclampsia, fetal growth restriction, pregnancy loss and/or stillbirth [2–6]. Together, these complications are leading causes of maternal and perinatal mortality and morbidity [7,8]. Additionally, spontaneous preterm birth may be due in part to placental abnormalities in the absence of other mitigating factors such as infection [5]. The burden of placenta-mediated complications also extends beyond the postpartum period, inferring increased life-long health risks for both mother and child [9].

Exact etiology and pathophysiology of placenta-mediated complications remain largely elusive. While a theoretical understanding of the causative role of this organ in the majority of obstetrical complications exists, the placenta often receives minimal attention in the clinical setting [10]. Practice guidelines from organizations such as the College of American Pathologists [11] and the Royal College of Pathologists [12] recommend placental examination for all adverse pregnancy outcomes listed above, in addition to pre-existing maternal disease and/or gross placental abnormalities. Despite these recommendations, studies suggest that upwards of 20–65% of placentas meeting criteria for examination are not sent for evaluation [13,14]. Reasons for low submission rates include lack of awareness of the need for examination, disagreement with criteria for submission, and lack of perceived clinical benefit of placental examination in patient management and counselling [13,15]. This is a missed opportunity, as detailed examination of the placenta following an adverse pregnancy outcome can provide insight into underlying pathophysiology of disease and can be used to inform clinical management of both the mother and neonate in the postpartum period [16–18]. Further, information collected from the placenta can allow for effective patient counselling regarding recurrence risks for subsequent pregnancies and life-long health [16,19,20]. In a research context, insight gained through placenta pathology can highlight critical mechanisms driving placental dysfunction, allowing for novel discoveries for prediction, diagnosis and/or interventions of placental-mediated pregnancy complications [21,22].

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2. Placental pathology – the current landscape

Clinical guidelines [11,12] detail a complete assessment of placental gross anatomy and histological examination of the umbilical cord, membranes and parenchyma. In routine practice, narrative reporting is the standard process for evaluating the presence and severity of histopathological lesions, with significant findings assembled into a final report. Unfortunately, this process is hindered by lack of standardization in nomenclature and classification of placental diagnosis, as well as quality issues related to the use of narrative reports [10,23]. A lack of consistency in terminology and criteria for lesion severity is a recognized concern by experts in the field [23,24]. Moreover, systematic reviews investigating associations between reported placental lesions and various pregnancy complications cite subjective, non-specific terminology and wide variability in diagnostic criteria between studies, making comparability and interpretation of findings difficult [17,25,26]. Likewise, the translation of research-focused endeavors into clinically meaningful outputs is limited by the high degree of heterogeneity in placenta pathology findings reported across clinically similar patient populations [27–29]. This variability may be due in part to study design (ex. cohort versus case-control studies), non-blinding of the reporting pathologist or differing lesion definitions used between studies [25,26,30,31]. A recent systematic review of pathological lesions in stillbirth stated that few studies described the diagnostic criteria used and, if this was described, nomenclature and severity differed between studies [25]. Together, these challenges limit the utility of placental pathology in the care of mother and baby [32,33] and in the advancement of our understanding of mechanisms underlying placenta-mediated pregnancy complications [34]. As suggested recently [24], we would argue that until the research and clinical communities universally move towards a standardized approach to placental examination *and* reporting, we will remain stalled in the effective integration of placental pathology findings into knowledge generation and clinical care practices.

A standardized approach in all aspects of placental pathology is required to increase its overall utility. As described below, approaches to address issues with standardization of nomenclature and diagnostic classification are well underway [16,24,35–39]. The next fundamental change needed in the field of placental pathology is the widespread *uptake* of synoptic reporting to overcome known challenges with narrative reporting. Here, we propose a synoptic framework for placental pathology reporting, which incorporates standardized placental examination and diagnostic criteria [11,12,16,24,36–38,40–44]. Additionally, this synoptic approach is poised to increase the clinical translation of placental findings to relevant stakeholder groups through a customized output that will bring placental diagnosis to the forefront in clinical care. Continued efforts in these areas will no doubt improve the consistency, reproducibly and quality of placental pathology and impact in clinical care and research practices in the future, as it has in other domains of pathology [45].

2.1. Standardized placental examination and lesion classification

Optimal practice would have placental pathologists throughout the world using the same terminology and severity criteria when describing and diagnosing placental lesions. In 2003, the Perinatal Section of the Society for Pediatric Pathology published a series of papers providing unified terminology and criteria for grading lesions of maternal vascular disorders, fetal vascular disorders, and amniotic fluid infection [36–38]. Following publication, efforts to disseminate these classifications for placental diagnosis were undertaken [10], culminating in the 2015 Amsterdam Placental Workshop Group Consensus Statement which established the most recent standard for placental examination and sampling, along with comprehensive terminology and classification for placental diagnosis with international consensus [16,24]. Recommendations for standardized gross examination by the Amsterdam Group include descriptions of trimmed placental weight, placental disk dimensions, umbilical cord and membrane features [24]. A minimum of four tissue blocks for histological examination should be submitted to the pathologist – one of the extraplacental membranes rolled from the rupture edge to the placental margin with two cross-sections of the umbilical cord (fetal end and 5 cm from insertion end) and three full-thickness blocks of normal-appearing parenchymal tissue. Additional blocks of macroscopic lesions with adjacent normal parenchyma should be submitted as required. Consensus for definitions and severity of placental lesions spanned the following categories of pathology: 1) maternal vascular malperfusion, 2) fetal vascular malperfusion, 3) delayed villous maturation, 4) ascending intrauterine infection and 5) villitis of unknown etiology [38]. The criteria for placental diagnosis set forth by this expert group should be adopted by clinicians and researchers at an international level. This would serve to improve the consistency and reproducibility of placental pathology examination and mitigate discrepancies in placental diagnosis in both clinical practice and research studies.

2.2. Reporting practices

In addition to global standardization of nomenclature and classification criteria for placental diagnosis, there must be a paralleled push to standardize the method by which pathologists evaluate and report the findings of a placenta examination. Currently, standard practice for placental pathology involves narrative reporting, a system subject to personal bias and quality issues [46–51]. Without a structured workflow, which ensures that all possible placental lesions and severity are collectively evaluated, completeness of the reporting is left to individual practice. As a consequence, the quality of placental reporting is known to vary considerably, from overly simplified to overly detailed, with high degrees of variability in reported findings [35]. If significant lesions are unintentionally missed or not included in the final report, clinical management of mother and baby may be compromised [20]. Conversely, if the final report includes irrelevant placental findings, meaningful information may be overlooked or misinterpreted. A 2013 study surveying obstetricians on the utility of placental pathology reports identified the use of a more streamlined report, with findings grouped according to lesion categories, over narrative reporting format as a means to improve interpretation and implementation of findings into clinical practice [52].

From a research perspective, robust and consistent placental pathology data collection is needed for the delineation of placental disease and association with maternal and fetal/neonatal outcomes during and after pregnancy [53]. The research utility of data collection via synoptic reporting has been demonstrated in the oncology subspecialties, with large-scale tumor registries in Ontario and California noting successes in capturing robust data for research purposes [54,55]. Placenta pathology data collected in a standardized fashion would easily lend to integration with population-based databases, allowing for comprehensive studies on placental-mediated diseases [53]. A clearer understanding of the associations between the presence of distinct placental lesions and maternal and neonatal health outcomes could help clarify our current disease paradigms for placental-mediated complications, and may help identify distinct subclasses of placental dysfunction in obstetrical disorders with considerable clinical heterogeneity, such as preeclampsia [22,56]. Standardized placental pathology data collection would also facilitate better case-control selection for observational and intervention studies, with pathology findings being easily comparable and reproducible between research centers. Quality placental pathology data is necessary in order to advance our knowledge of placental dysfunction, determine clinically significant thresholds for placental diagnosis and ultimately, refine our understanding of placental lesions associated with adverse pregnancy outcomes and long-term health outcomes for mothers and babies.

3. The future - moving beyond narrative reporting in placental pathology

Other fields of pathology have moved beyond the use of narrative reporting to a more standardized approach known as synoptic reporting. A synoptic pathology report includes line-by-line evaluation of specific lesions important in the classification and diagnosis of the particular pathology. The College of American Pathologists has developed criteria for synoptic reporting that states: 1) all required data elements must be paired with responses and be included in the report; 2) each required data element and response is listed on a separate line; 3) if multiple responses are permitted, each response must be on a separate line; 4) all required data elements and responses must be listed together with the synopsis appearing separately; and 5) narrative descriptions are allowed in addition to the required data elements and responses but are not a substitute for them [57]. Narrative comments may reference required data elements but cannot replace entry of the information in the synoptic report [57].

The benefits of synoptic vs. narrative reporting in pathology include improved completeness, enhanced communication between pathologist and clinicians and improved facilitation of information exchange between key parties. Studies suggest that synoptic reporting can improve the completeness of reporting upwards of 60–94% compared to narrative reporting [58–64]. Likewise, synoptic reports reduce the amount of superfluous content, improving the conciseness of the report for the reader and facilitate improved communication between pathologist and clinician using consistent terminology [58,61,64,65]. Further, clinician satisfaction increases with the use of synoptic reports due to ease of finding information for clinical decision-making and the consistent approach to interpreting findings [65–67]. Synoptic reporting also streamlines workflow, and when computerized can provide data entry restrictions (e.g. units of measure) and notifications for missed data fields, further improving the accuracy and completeness of the report [59,68,69].

A synoptic reporting approach has not been undertaken with any degree of significance in the field of placental pathology, unlike other areas of pathology. However, several groups have proposed systematic reporting schemes for placental pathology to improve quality and clinical utility of reports as well as enhance the robustness of data collection for research purposes [40–42]. While these schemes include a structured checklist, several components outlined by the College of American Pathologists are missing, such as data elements paired with discrete responses, listed line by line [57]. Further, a paucity of studies evaluating the uptake of these published reporting schemes exists, so their utility over narrative reporting in this field remains unknown. However, growing evidence collected in other fields of pathology lend strong support for improved placenta pathology report completeness and quality should a synoptic approach be adopted universally, ultimately benefitting maternal-fetal clinical practice and research endeavors.

3.1. A synoptic framework for placenta pathology reporting

The consensus work undertaken by the Society for Pediatric Pathology, the Stillbirth Alliance and, most recently, the Amsterdam Working Group [10,24,36–38,42] has established the basis for universal nomenclature, diagnostic criteria and sampling protocols. We propose a framework (Table 1) that builds on the standardization and optimization across the *subsequent* critical components of placental pathology: 1) synoptic reporting of placental lesions and 2) optimized clinical translation tailored to relevant stakeholder groups. This evolved framework has the potential to improve how placental pathology is conducted, allowing for clinicians and researchers alike to take full advantage of this powerful clinical tool along its continuum – from the view under the microscope through to clinical translation.

3.1.1. Synoptic reporting of placental lesions

Within the framework, placental lesions are arranged into etiological-based categories representing well-described pathophysiological processes associated with placental disease. These categories include: maternal vascular malperfusion, decidual vasculopathy, implantation abnormalities, intrauterine infection, placenta villous maldevelopment, fetal vascular malperfusion, chronic uteroplacental separation, maternal-fetal interface disturbance, and chronic inflammation. An "Additional Findings" category is included for inclusion of rare lesions not commonly encountered. Each lesion has a discrete entry field for indicating its presence or absence or for indicating the severity grade of the lesion where applicable. Likewise, there is a text field for narrative descriptions at the end of the framework should the pathologist wish to include them. Evaluation in this format would ensure that all critical lesions are assessed and pertinent negatives are recorded for each placenta, and provides final reports with a consistent format. Additionally, this synoptic format has the potential to improve the reporting quality by non-subspecialty trained pathologists at centers without a placental pathology specialist. As shown in other domains of pathology, use of synoptic reports by non-subspecialty trained pathologists increased the completeness and utility of final reports [45,70].

The inclusion of explicit definitions for each lesion along with relevant severity criteria embedded directly in the framework removes interpretational grey areas and personal bias. All major pathological categories and accompanying lesions, with descriptions and severity grading, outlined in the Amsterdam statement are included in the framework [24]. We have also included additional categories and lesions pertinent to placental examination that are not covered in the Amsterdam document, but have been previously described in the literature. For example, we added a data field for villous agglutination in the category of maternal vascular malperfusion as it was not directly commented on by Amsterdam group but was previously described by Redline et al. [38] The lesion may represent focal mild sub-infarctive anoxic change, however this has yet to be elucidated. Recording its presence and severity may allow for associative studies in future research. We also created a separate section for maternal decidual vasculopathy, whereas these lesions were included in the maternal vascular malperfusion category by Amsterdam. Our rationale for this separation was to delineate lesions occurring in the parenchyma versus the maternal decidua. Other lesions (in addition to the major Amsterdam categories) include microscopic accreta/basal plate myometrial fiber, specific inflammatory patterns associated with bacterial and fungal infection, chorangiosis, chorangiomas and rare but recurrent and serious conditions such as massive perivillous fibrinoid deposition and chronic intervillositis.

3.1.2. Optimized clinical translation tailored to relevant stakeholder groups: A future direction

Placental diagnosis can reveal the underlying cause of adverse pregnancy outcomes, identify complications with a high recurrence risk and provide information for the immediate and future care of mother and infant [16,17,41,71]. However, if interpretation of pathology findings and their clinical relevance are not adequately communicated to the appropriate care providers, this critical information is lost. An often-overlooked aspect of placenta pathology standardization efforts is the translation of placental findings and their clinical significance into outputs tailored to the distinct stakeholder groups who would benefit most from the findings. We envision a final pathology report individually tailored to distinct clinical care provider groups, such as obstetricians, neonatologists and family physicians. Putting the significance of specific pathological findings, and associated risks and outcomes (both present and future), into context for the receiving clinician would allow for better patient management and counselling. Following a summarized diagnostic comment, specialty-specific outputs would provide the contextualized clinical relevance of the pathology findings. Correlations with clinical diagnoses, immediate postpartum

Table 1
Synoptic framework for placental pathology [97,98] > .

Gross examination	
State □ Fresh □ Fixed	
Trimmed placental weight : _____ grams **Placenta weight percentile :** _____ *derived from local population standards[33] **Complete basal plate**: Yes or no	
Placental Disk[33]	
Maximal linear length	_____ cm
Maximal width (perpendicular to liner length)	_____ cm
Minimal thickness	_____ cm
Maximal thickness	_____ cm
Accessary lobes?	Yes or no Size: ____ cm
Umbilical Cord[33]	
Maximal diameter	_____ cm
Cord length	_____ cm
Velamentous cord insertion?	Yes or no If yes, _____ cm from disc margin
Color	_____
Marginal cord insertion? *<1cm from nearest margin*	Yes or no
Peripheral cord insertion? *<3cm from nearest margin*	Yes or no
Handedness of coiling	□ Right or □ left or □ Could not be determined
Hypercoiling of cord? *>3 coils per 10cm*	Yes or no
Segmented hypercoiling?	Yes or no
Presence of deep grooves between coils?	Yes or no
Hypocoiling of the cord? *<1 coil per 10cm*	Yes or no
True knots?	Yes or no If yes, tight or loose
Membranes[33]	
Colour	_____
Completeness	_____
Extrachorialis?	Yes or no Circumvallate or circummarginate
Localised lesions *separate entry for each distinct lesion observed	
Location: central or peripheral **Number of lesions:** _____ **Maximal dimension:** _____ x _____ x _____ **Percentage of placental disc volume involved**: _____ % Specified or non-specified Textbox - description	
Retroplacental hematoma (compression of overlying parenchyma) **Location:** central or peripheral **Maximal dimension:** _____ x _____ x _____	
Diffuse parenchymal consolidation? Yes or no Greatest thickness : _____ mm Estimated volume as a percent of total disc volume : _____ %	

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Table 1 (*continued*)

Microscopic Lesions
Category 1 : Evidence of maternal vascular malperfusion
Placental infarct(s)[33] • *Refer to gross description, exclude marginal infarctions in a term placenta* 0 = No 1 = Yes; Indicate if: □ Early (crowding/congestion of villi, may be hemorrhagic, early loss of stromal nuclear staining) OR □ Remote (necrotic changes, loss of trophoblast nuclear staining and ghost villi)
Distal villous hypoplasia[33] • *Reduction in size of intermediate villi with dispersed terminal villi and reduced number that appear thin and elongated, widening of intervillous space; adjusted for gestational age; involves at least 30% of full thickness slide* 0 = Not present 1 = Focal (1 slide only) 2 = Diffuse (≥2 slides)
Accelerated villous maturation pattern[33] • *Presence of term-appearing/hypermature villi for gestational age, not in areas adjacent to infarction* 0 = Not present 1 = Diffuse pattern (seen on 2 or more slides)
Increased syncytial knots[33] • *Aggregates of syncytiotrophoblast nuclei along stem and/or at terminal villi involving 33% of the villi or more* 0 = Not increased 1 = Increased (defined as knots on more than 33% of the villi)
Villous agglutination[49] • *Clusters of adherent terminal villi (>2, <20), enmeshed by fibrin and/or bridging syncytial knots and/or apoptotic debris assessed at 4-10X magnification* 0 = Not present 1 = Present, focal (present on 1 slide only) 2 = Present, present on 2 more slides
Category 2 : Evidence of maternal decidual arteriopathy
Insufficient vessel remodelling[33,49] • *Unremodelled vessels with retained muscularis and elastin (capsularis) or any retained muscularis or elastin (basalis)* 0 = Not present 1= Present; Location: decidual capsularis or basalis or both
Fibrinoid necrosis[33,49] 0 = Not present 1 = Present 2 = Present with atherosis (foamy histocytes); Location: capsularis or basalis or both
Category 3 : Implantation site abnormalities
Microscopic accreta[97] 0 = Not present 1 = Present, basal plate with myometrial fibers with intervening decidua 2 = Present, basal plate with adherent myometrial fibers, ≤2 layers of decidual cells separating myometrium from anchoring villi/Rohr's fibrin

(*continued on next page*)

Table 1 (*continued*)

3 = Present, myometrial fibers directly adherent to Rohr's fibrin/anchoring villi (equivalent to pathologic accreta)
Category 4 : Evidence of ascending intrauterine infection[33,47]
Maternal inflammatory response (exclude subchorionitis) **Stage:** 0 = Not present 0+: Neutrophils in subchorionic fibrin only1 = Stage 1 – neutrophils in trophoblast layer of membrane 2 = Stage 2 – diffuse or patchy neutrophils in fibrous chorion or amnion 3 = Stage 3 – amnion or chorionic plate necrosis
Grade: 0 = Not present 1 = Mild or moderate – lacks criteria for Grade 2 2 = Severe – confluent neutrophils between chorion and decidua, greater than 10 x 20 cells in extent with greater than 3 foci or a large continuous band
Fetal inflammatory response **Stage:** 0 = Not present 1 = Stage 1 – chorionic vessel vasculitis or umbilical venous vasculitis 2 = Stage 2 – umbilical vasculitis with umbilical arteritis 3 = Stage 3 – necrotizing funititis/concentric umbilical perivasculitis
Grade: 0 = Not present 1 = Mild to moderate – lacks criteria for Grade 2 2 = Severe – heavy inflammation of vessel within the umbilical cord or chorionic plate vessel with vessel wall damage
Thrombosis of any of the umbilical or chorionic fetal vessels present**:** Yes or no
Category 5 : Evidence of placenta villous maldevelopment
Chorangiosis[83] • *Hypercapillarised terminal villi* 0 = Not present 1 = Present with >10 terminal villi with ≥10 capillaries, seen in 2 or more slides
Chorangiomas[83] 0 = Not present 1 = Present and < 3 cm in size 2 = Present and ≥ 3cm in size or >5 total nodules
Delayed villous maturation[33] • *Monotonous villi (≥10) with centrally placed capillaries and decreased vasculosyncytial membranes resembling villi in early pregnancy, present in at least 30% of full thickness section* 0 = No villous immaturity 1 = Focal – lesion seen on one slide only 2 = Diffuse – seen on ≥2 slides
Category 6 : Evidence of fetal vascular malperfusion[33]
Avascular fibrotic villi (requires the absences of VUE) 0 = None present 1 = Small foci – 3 or more foci of 2-4 terminal villi showing complete loss of villous capillaries and bland hyaline fibrosis of the villous stroma 2 = Intermediate foci – 3 or more foci of 5-10 terminal villi 3 = Large foci – 3 or more foci of >10 villi
Thrombosis 0 = Not present

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Table 1 (*continued*)

1 = Present Location : Umbilical, chorionic plate, stem vessel Number : _____ ; □ Occlusive OR □ Non-occlusive
Intramural fibrin deposition • *Subendothelial or intramuscular fibrin or fibrinoid deposition within the wall of large fetal vessel (recent), with calcifications (remote)* 0 = Not present 1 = Recent, Number: _____ 2 = Remote, Number:_____
Villous stromal-vascular karyorrhexis • *≥3 foci of 2-4 terminal villi showing karyorrhexis of fetal cells with preservation of surrounding trophoblasts* 0 = Not present 1 = Present
Stem villous vascular obliteration 0 = No 1 = Yes
High-grade fetal vascular malperfusion • *≥1 focus of avascular villi (≥45 cumulative avascular villi over 3 sections, average of ≥15 villi per section) with or without thrombus OR ≥2 thrombi in chorionic plate or major stem villi OR multiple non-occlusive thrombi* 0 = Not present 1 = Low-grade (does not achieve high-grade criteria); □ Segmented OR □ global 2 = High-grade; □ Segmented OR □ global
Category 7 : Evidence of utero-placental separation[33,83]
Chorionic hemosiderosis 0 = No 1 = Yes
Presence of retroplacental adherent hematoma • *Refer to gross description, confirm histologically; compressive overlying parenchyma* 0 = No 1 = Yes; Overlying infarction? Yes or No
Category 8 : Fibrinoid
Increased focal perivillous fibrin deposition[52] **(perivillous fibrin plaque)** • *Increased amounts of fibrin coating proximal stem villi and/or terminal villi* 0 = Not present 1 = Present; Percentage of total parenchyma occupied: _____ %
Massive perivillous fibrin deposition pattern[83] 0 = Not present 1 = Diffusely present, 30-50% of intervillous volume, seen on at least 2 slides 2 = Diffusely present, >50% of intervillous volume, must be seen on all slides
Maternal floor infarct pattern[83] Histological confirmation : yes or no
Category 9 : Intervillous thombi
Intervillous thrombi 0 = Not present 1 = Present, confirmed histologically

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Table 1 (*continued*)

Category 10 : Evidence of chronic inflammation
Villitis of unknown etiology[33,43] 0 = Not present 1 = Low-grade, inflammation affecting <10 contiguous villi in any one focus, >1 focus ** □ Focal (1 slide only) OR □ multifocal (>1 slide)* ** Avascular villi: Yes or No* 2 = High-grade VUE – inflammation affecting >10 contiguous villi, seen in multiple foci on >1 section ** □Patchy (multiple foci, 1 with >10 contiguous villi) OR □ diffuse (>30% of all terminal villi involved)* ** Avascular villi: Yes or No*
Chronic intervillositis[98] • *Infiltration of the intervillous space by histocytes* 0 = Not present 1 = Present; Percentage of intervillous volume occupied: _____ %
Chronic plasma cell deciduitis[33,44] 0 = Not present 1 = Present
Chronic chorioamnionitis[39] • *Infiltration of mononuclear cells into the chorioamniotic membranes or chorionic plate* 0 = Not present **Grade:** 1 = >2 foci of inflammation or patchy inflammation 2 = diffuse inflammation present **Stage:** 1 = Amniotropic lymphocytic infiltration limited to chorionic trophoblast layer sparing chorioamniotic connective tissue 2 = lymphocytic infiltration into chorioamniotic connective tissue
Additional findings
Single vessel cord 0 = No 1 = Yes
Meconium histiocytes/macrophages within membranes 0 = Not present 1 = Present
Meconium-induced myonecrosis 0 = Not present 1 = Present
Narrative comment:

and long-term health risks for mother and baby, as well as recurrence risks for future pregnancies would be highlighted.

Fundamental to these tailored report outputs is the inclusion of a largely ignored stakeholder group – the patients themselves. Over the past two decades, healthcare in North America has moved towards the patient-centered model, involving patients in all aspects of their care as a way to improve quality of care, ensure patient safety, and enhance patient satisfaction [72,73]. As part of the patient engagement movement, an increasing number of patients are gaining access to their healthcare information via patient-accessible electronic medical records (EMRs) [74]. Laboratory results, including pathology reports, are amongst the most frequently accessed pieces of information in patient-accessible EMRs [75,76]. Placental diagnoses, explained in accessible terms, could offer invaluable explanations for adverse pregnancy

outcomes or the cause of stillbirth [25]. Having an explanation as to why an adverse pregnancy outcome occurred, especially in the case of perinatal loss, has been identified as an important component in the healing and bereavement experience of parents [33,77]. Likewise, patients could be made aware of future risks, both pregnancy recurrence risks and long-term health risks, and be advised to seek specialist care in the postpartum period [78].

Effective stakeholder-specific translation of placenta pathology should include descriptions of findings that are both available and understandable to the patients themselves. In oncologic pathology, the creation of plain-language tools to interpret pathology reports is in its nascency. The American Cancer Society has created resources to aid patients in understanding their cancer pathology reports, however, they are limited to five anatomic areas: breast, colon, esophagus, lung, and prostate [79]. In Canada, a more comprehensive pathology education resource for patients is available (MyPathologyReport.ca), which offers a pathology dictionary as well as patient-centered diagnostic articles for over 65 clinical entities [80]. This resource, however, currently focuses on neoplastic processes and does not include any form of patient information surrounding placenta pathology. The incorporation of patient-centered summaries into pathology reports is even more limited. A small number of pilot programs across North America have emerged, and while preliminary, results suggest that patient-centered reports improve patient knowledge regarding diagnosis and facilitates shared-decision making between patient and clinician [81]. We believe that tailored, patient-centered reporting is the future of pathology and is a novel and important part of our proposed synoptic reporting framework.

A hypothetical example of our tailored pathology output is presented in Fig. 1. In our example, the obstetrical output for a placental diagnosis of maternal vascular malperfusion includes confirmation that placental findings reflect the clinical outcomes (preeclampsia and fetal growth restriction), their correlation with ultrasound and Doppler findings, as well as the recurrence risk for subsequent gestations. The neonatology output focuses on the placental findings in the context of warranted infant surveillance, such as observation for signs of neurological injury. The output for family practice includes recommendation for referral to high-risk obstetrical services for preconception counselling and/or subsequent pregnancies. The output also indicates the long-term health risks associated with the diagnosis, namely premature cardiovascular disease. As previously described, this framework envisions a unique opportunity to generate a tailored output report for a high priority stakeholder group – the patients themselves. This output would include a lay summary of the placental findings, the significance of these findings for mother and infant health as well as specific follow-up care the patient could request. Such an approach places the patient at the center of their care and improves the accessibility of this important clinical modality.

4. Obstacles to uptake and implementation synoptic reporting

There are identified obstacles that might limit both the universal uptake and implementation of the synoptic framework into routine clinical practice. The most obvious of which would be the perceived and/or realized increase in time allotment per case required to properly complete the highly structured placenta pathology examination. Uptake would initially involve an increased time investment by the pathologist due to the learning curve associated with the format and structure of

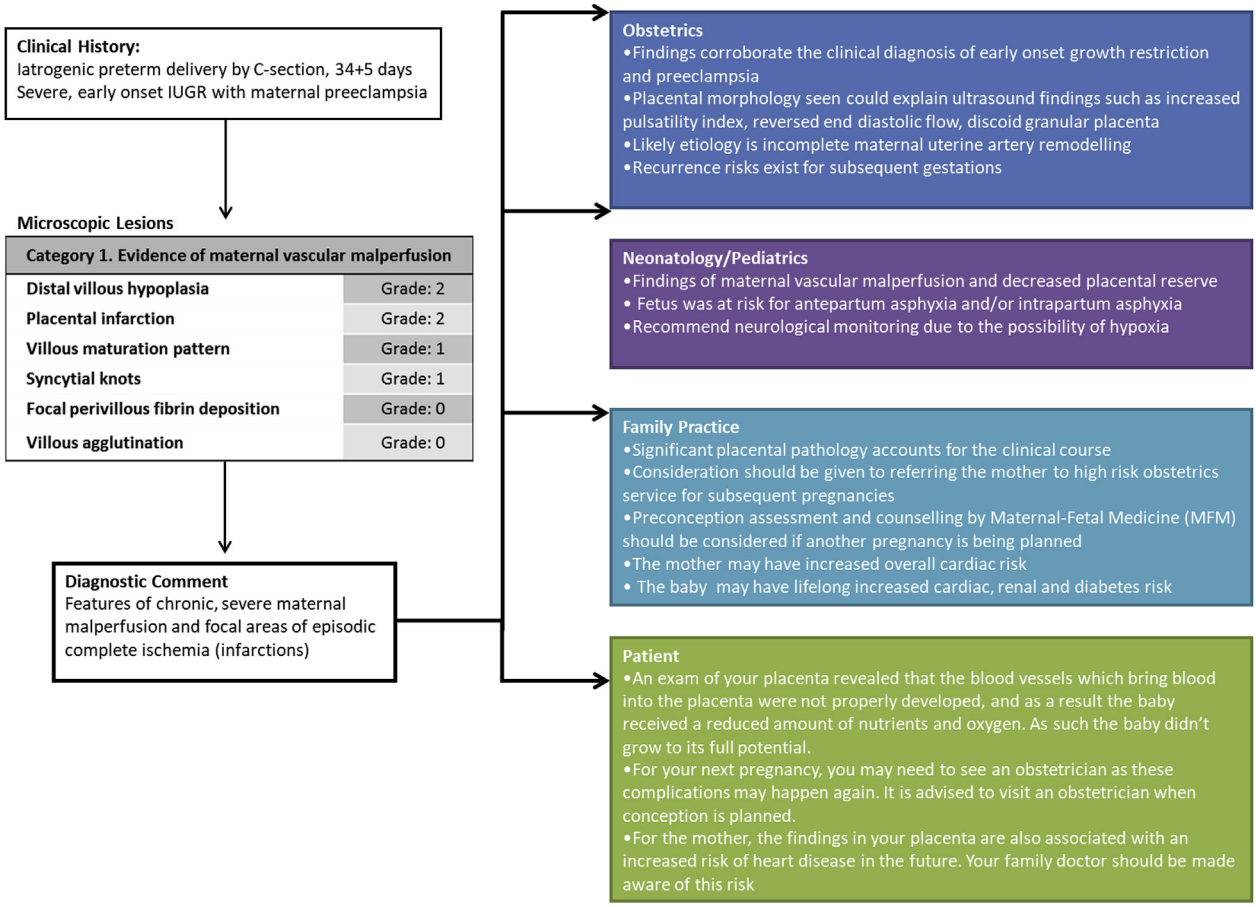

Fig. 1. Hypothetical tailored outputs from the synoptic framework for placental pathology. Following examination of the placenta and findings recorded using a standardized synoptic framework, clinical relevance of the placental diagnosis is tailored to each specific stakeholder group, namely obstetricians, neonatologists/pediatricians, general practitioners and patients.

the framework. While this might be a challenge to initial uptake in routine practice, other areas of pathology suggest that allotted time required per case gradually declines as familiarity with the tool increases [47]. Likewise, the improved quality of the examination and final report have been cited to outweigh additional workload brought upon by standardized reporting [47]. It will be critical for future research to validate the benefit of standardized placenta pathology exam in the patient care continuum to receive support from pathologists and hospital administration alike [47,82], allowing for appropriate workload allocation for cases of placenta-mediated diseases.

Further, validation of this tool is necessary across large and small clinical centers to determine uptake, reproducibility and maintenance workload of the framework and its impact on clinical care. It will be imperative to draw on the experience within the field of cancer pathology, where electronic synoptic reporting has been implemented across many different centers of varying sizes and degree of sub-specialization, to negotiate these barriers and ensure success for synoptic placental pathology reporting [47,58,83–86]. In those smaller centers, which may have non-subspecialty trained pathologists providing placental pathology reports, training will be required to encourage uptake. While subspecialty-trained perinatal and placental pathologists would gain exposure through their fellowship and residency curriculums, widespread dissemination and training via professional associations and societies such as the Society of Pediatric Pathologists (SPP) could aid in this endeavor, similar to the online and conference-based dissemination of cancer synoptic reporting by the College of American Pathologists (CAP).

An additional barrier to implementation in routine clinical practice would be the integration of the framework into existing reporting modalities already in use. At present, the framework is in a paper-based format, which would likely deter pathologists from using it. Efforts to develop the framework into an electronic platform are underway and will reduce the time required to complete the comprehensive placental exam and generate tailored reports. The translation of this conceptual framework into an electronic platform would require integration with electronic reporting systems used by individual institutions and presents a logistical undertaking by hospital administration. Additionally, maintenance of the program would be required to ensure definitions and severity criteria for placental lesions, and the clinical significance of these lesions remain up-to-date. As our knowledge continues to advance and research informs clinical practice, our synoptic report will need to adapt accordingly. As we have seen in oncologic pathology, there is an increasing amount of cancer biomarker data being incorporated into synoptic reports, including genomic and biomolecular information [87]. Should biomarkers similarly become commonplace in placental pathology, standardized reporting of this complex information will become critical.

Finally, a barrier to the implementation of any change in reporting is the perception of liability. Particularly in the era of patient-accessible electronic medical records, concerns surrounding error and error-disclosure on behalf of both the pathologist and clinician continues to permeate medicine in general, and the field of pathology more specifically [88–90]. There is evidence that high quality communication with patients decreases risk of litigation and increases patient's sense of quality and overall perception of safety [74,91–94]. The landmark 2015 consensus study report by the National Academies of Sciences, Engineering, and Medicine entitled Improving Diagnosis in Health Care stated that pathologists must take on a more prominent role as patient care providers and collaborate more effectively with their clinician colleagues as it relates to patient safety [95,96]. Pathologists have been called upon by the medical community to become more active participants in the patient safety movement and we believe this synoptic report, with the future inclusion of a patient-centered summary, will allow pathologists to do so.

5. Summary

The most prevalent and serious obstetrical complications faced in today's health care system share at least one thing in common – evidence of placental disease and damage. While acknowledging the considerable burden of placenta-mediated disease on maternal and fetal health, the lack of clinical focus on the placenta following delivery is an opportunity missed. Efforts to bring the practice of placental pathology front and center in the diagnosis and management of placenta-mediated diseases have been made recently, with several experts in the field pioneering global standardization efforts. We aim to contribute further to these endeavors through our proposed framework – focusing specifically on the standardization of synoptic reporting and knowledge translation modalities. We believe this conceptual framework has the potential to revolutionize how placental pathology is conducted and perceived by the clinical, scientific and patient communities.

Conflicts of interest

The authors report no conflict of interest.

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Appendix A. Supplementary data

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