

Improving safety during birth, a universal question for a non-universal practice

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Birth is entangled into our very survival as a species. The concept of safety *during* birth, however, has evolved drastically in the last centuries. Despite advances in the mid-19th to early 20th century, the clinical decision to proceed with vaginal labour is still not unified between countries or clinicians and remains mostly subjective in nature and/or guided by regional habits. This Insight synthesises the discussion, concluding thoughts and proposed action points of an international series of workshops on improving safety during birth through multidisciplinary collaboration.

Injury or not?

The very definition of “injury” during vaginal birth is alarmingly ill-defined. In fact, birth is arguably amongst the most dangerous periods for the foetus with regards to risk of brain injury, though much of this is related to hypoxic ischaemic injury associated with abnormal oxygen delivery [1]. Skull fracturing is thought to be rare, with the caveat that the actual occurrence is likely to be greater than those commonly seen in clinical practice because of asymptomatic cases. In fact, the distinction between “normal” and “abnormal” becomes further entangled when considering the risk of bleeding in the brain, especially in the subdural space. While these bleeding events are expected to be reabsorbed in most cases, an acute bleed may theoretically become chronic. Said otherwise, it is not the event itself that defines the injury but its consequences. Maternal bleeding is similarly expected following birth. However, above 500 mL, and abnormal or excessive bleeding from 24 hours to 12 weeks postpartum are defined as primary and secondary postpartum haemorrhage (PPH), respectively. Regardless of the cause of PPH, short-term complications include hypovolaemic shock and transfusion reactions to blood products while long-term risks include postpartum pituitary insufficiency and PPH in subsequent pregnancies. Trauma to the vaginal mucosa and perineal muscles (second degree tear) affects up to 80% of women [2] while trauma to the anal sphincter or rectal mucosa, or obstetric anal sphincter injury (OASI), occurs in 6% of vaginal births. Anal incontinence, recto-vaginal fistula and dyspareunia can occur in women following OASI with long-term implications [3]. Equally, the psychological impact of birth and complications cannot be overlooked, as highlighted by the UK Parliamentary Report on Birth Trauma. Similarly to the infant, what constitutes an injury in the first place is heavily conditioned by its mid- to long-term consequences.

Injury or not, the aim is to minimise the risk of negative consequences through the consideration of spontaneous vaginal birth, assisted vaginal birth (rotational or non-rotational) with forceps or vacuum, and caesarean birth either electively planned or in emergency setting. In the era of shared decision-making, women must be empowered with evidence-based knowledge antenatally [4]. When proposing an intervention, healthcare professionals should seek informed consent, providing an explanation of risks and benefits for all reasonable alternatives; and – when relevant – decline an intervention considered as unsafe when potentially leading to avoidable trauma. Such decision-making process requires data.

Acquiring data

Recent technological advances aimed at acquiring such data are mainly organised along three lines:

Sensing/imaging before and during labour. These are, among others, Foetal Heart Rate monitoring [5], Ultrasound Imaging with AI-based Segmentation [6], MRI and Advanced Imaging Modalities [7] with some emerging technologies such as Electrohysterography and Near-Infrared Spectroscopy [8], and wearable sensor systems [9]).

Digital twins (DTs) and predictive models. DTs comprise: the physical entity in the real world (e.g., patient and foetus), a digital representation and the data layer that connects them [10]. This system continuously collects maternal-foetal data and transforms it into a real-time digital representation, ideally enabling a seamless link between the biological and digital environments.

Sensorised devices. Recent advancements in biomedical engineering have introduced sensorised devices aimed at enhancing clinical precision and patient safety during operative deliveries. Sensorised instruments represent a practical interface between clinician and patient, providing tactile and quantitative feedback during labour [11].

Current efforts aim at integrating these various modalities into unified platforms supported by a DT-focused decision tools to improve labour monitoring precision and maternal-foetal outcomes [12]. A widespread clinical adoption, however, awaits further validation and technological refinement.

Using the data

The emergence of artificial intelligence (AI) technologies creates exciting opportunities. This, however, require well curated datasets of a broader wealth of obstetric variables, rather than those surrounding the narrow time-point of the birth: e.g., complete maternal demographic and anthropometric information, medical and obstetric history, pregnancy biomarkers of maternal and foetal health, ultrasound and doppler parameters of foetal growth, functional tests of antepartum and intrapartum foetal wellbeing, structured assessments of foetomaternal position, engagement, descent and cervical dilatation, and logs of medical and pharmacological interventions. Appropriately structured and maintained, these datasets could then be interrogated by AI tools to identify candidate associations and formulate decision aid-tools.

At the same time, AI analyses should not be seen as a panacea: association does not prove causation. The value of an AI-aided tool is to identify patterns of pregnancy care and early warning systems to minimise the likelihood of a complicated emergency birth. As those patterns are taken into account in new decisions, the AI tool needs to be retrained as the original training data becomes obsolete.

Focusing instead on “cause and effect”, computational mechanistic models have been used in the field of engineering to understand and analyse the physical behaviour of complex engineering systems, e.g., to understand the mechanical mechanisms underlying outcomes in labour [10].

To combat both the computational expense of mechanistic models, the large datasets required, and the “black-box” nature of traditional AI, the two approaches can be combined (“mechanistic learning”). Mechanistic simulations can be used to augment data, adding in

mechanics informed information, while the traditional AI can interpret the mechanics into injury while also considering the non-mechanical factors that also influence risk of injury.

What's next?

The main emphasis is first and foremost on reducing maternal and neonatal morbidity and mortality [13]. As highlighted by the WHO, access to technology is highly disparate. It is thus imperative that any new technology be evaluated from multiple contexts of use, and, in particular, both high- and low-resource settings; and that it account for local training capabilities, cultural practices, and infrastructure. This major point aside, we argue for the following five points of technological actions, see panel.

- (i) *High-resolution data & longitudinal interpretation.* Beyond categorical variables, quantitative force trajectories, positions, durations, practitioner motion, uterine contraction strength, real-time foetal head orientation must feed into longitudinal outcome follow-ups, peer review and consensus building tracking neurodevelopment, motor skills, cognitive and/or musculoskeletal health. Going beyond retrospective observations, this calls for integrated perinatal-developmental registries, analyses and interpretation.
- (ii) *Mechanistic learning (MxL).* AI and machine learning (ML) excel at trends and interpolation, but mostly lack understanding¹. Mechanistic models can predict the loads and deformation both mother and foetus experience. Coupling both will elucidate what mechanical metrics significantly influence these loads and deformations, *what* the potential mechanisms of injury are and *why* [14].
- (iii) *Personalised holistic models.* DTs can be built from maps of maternal pelvis obtained via ultrasound or MRI, quantification of maternal soft-tissue elasticity through elastography, modelling of contraction waveforms using internal pressure sensors and/or externally monitored dynamics, use of ultrasound/3D imaging of foetal head geometry and MxL-enabled real-time prediction of outcomes. They need to be fast, to help reconsider position, delay interventions, or opt for elective measures before crossing thresholds.
- (iv) *Sensorised tools and training platforms.* Obstetrics training and birth assistance relying on tactile perception can be enhanced with sensorised devices to enable detection of foetal orientation, measure grip force, orientation, tissue contact, etc. Training programs can calibrate tactile responses to established thresholds via integration with virtual reality platform with haptic feedback, or physical replica of biological tissues and structures (phantoms), and can improve instrument deliveries.
- (v) *Objective damage assessment.* Despite evidence of intracranial haemorrhages in high percentage of vaginal deliveries, most infants show no short-term neurological deficits. A successful definition/prediction of *injury* and *safety* require SWI-MRI or high-resolution cranial ultrasound done in controlled cohort studies, scheduled developmental follow-ups (up to at least 5 years) and creation of a data registry.

¹ The authors are acutely aware of the significant amount of ongoing research currently focused on this topic. However, a discussion on this topic goes beyond the scope of this perspective and we restrict this observation to currently widely used methods.

To succeed, these action points require one last paramount action point: the need for *interdisciplinary research*. Given the complexity of Birth, we must build joint research-and-practice hubs interfacing sensor and robotics teams with labour units, emphasise joint modelling-development teams, share data systems and outcome registries and be open to oversight, and analytic reviews across disciplines. Only an integration of all disciplines and embedded interdisciplinary approach will lead to an appropriate definition of what safe birth means in a given community, for a given individual and what levels of risks must be adhered to.

Acknowledgment: This perspective was prepared thanks to the support of a UoO/UCL led workshop series on this topic and funded through AJ/AC's EPSRC IAA grant and the Wellcome/EPSRC Centre for Interventional and Surgical Sciences (WEISS) (203145Z/16/Z). All authors contributed to the piece.

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