Title: Implications of vaginal instrumental delivery for children's school achievement: a population-based linked administrative data study

Short Title: Implications of vaginal instrumental delivery

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ABSTRACT

BACKGROUND: Vaginal instrumental delivery is a common obstetrical intervention but its effect on children's later health and development is unknown.

AIMS: To determine if vaginal instrumental delivery is associated with adverse neurodevelopment (school achievement).

MATERIAL AND METHODS: We performed a population-based study involving linkage of routinely collected perinatal data with school assessments among children born in South Australia from 1999 to 2008. Participants were singleton children born by forceps (n = 5494), ventouse (n = 6988), or normal delivery (n = 80,803). Neurodevelopment (School achievement) was measured through performance on the National Assessment Program in Literacy and Numeracy (NAPLAN), at around eight years of age. This assessment involved 5 domains and scores were categorised according to performing at or above National Minimum Standards (NMS). Effects of instrumental versus normal vaginal delivery were analysed via augmented inverse probability weighting (AIPW), taking into account a variety of maternal, perinatal and socio-demographic characteristics.

RESULTS: In unadjusted analyses, instrumental delivery was not associated with poor NAPLAN scores. AIPW analyses also suggested that instrumental delivery had minimal adverse effect on NAPLAN scores, with the largest difference being lower spelling scores among ventouse-delivered children (-0.04 (95% CI -0.05, -0.02)) compared with spontaneous vaginal births. The findings were consistent among exploratory subgroup analyses involving births in the absence of prolonged labour, with APGAR≥9, and among normotensive and non-diabetic mothers.

CONCLUSION: In singleton children born at term, instrumental delivery does not have an adverse effect on neurodevelopment (school achievement) as measured by school performance at age eight.

INTRODUCTION

Instrumental vaginal delivery is a common obstetrical intervention. In Australia in 2011, instrumental deliveries accounted for 12.1% of all births[1]. This is comparable to UK figures of between 10-13%[2,3]. Indications for instrumental delivery include protracted second stage of labour, suspicion of immediate or potential foetal compromise, and deliberate shortening of the second stage due to maternal conditions limiting the ability to push. However, no indication is absolute and individual assessment of the benefits versus increased risks of instrumental compared to normal vaginal delivery is made on a case by case basis.

For the mother, the per partum risk of instrumental vaginal delivery includes soft tissue tears, abrasions, as well as anal sphincter or voiding dysfunction. These maternal risks are higher when delivering via forceps than via ventouse[4]. Short-term risks to the foetus are mainly that of trauma and include intracranial, sub aponeurotic, and subgaleal bleeding, skull and cervical spine injuries, facial or scalp lacerations, cranial nerve and ophthalmic injuries, as well as neonatal jaundice and hyperbilirubinaemia. The prevalence of these injuries vary slightly between forceps and ventouse delivery and are related to the way in which forces are applied to the foetal head[5]. Overall however, foetal risks are higher when delivery via ventouse then via forceps[6 7].

Despite the increased risk of foetal head injury, the long-term neurodevelopmental effect of instrumental delivery is still unclear. A comparison of forceps, ventouse, and caesarean deliveries favoured forceps delivery as being least likely to cause short-term adverse neonatal neurologic outcomes[8]. In another randomized controlled trial,

developmental outcome at 5 years of age was similar for both forceps and ventouse births[9]. It has recently been shown that children born of caesarean section and normal vaginal delivery have comparable school performance at age 8.[10] However, long-term effects of instrumental versus spontaneous vaginal delivery on developmental outcomes are currently lacking. We therefore investigated whether birth by forceps, ventouse, or normal vaginal delivery affected school achievement at age eight.

MATERIALS AND METHODS

In this whole-of-population study, we linked three de-identified, routinely collected datasets from the Australian and South Australian governments. Primary study approval was provided by the South Australian Department for Health and Ageing (HREC/15/SAH/61). Datasets were obtained from the relevant government agencies with approval. ~~As the dataset has been de-identified, consent from individuals in this population study was not possible.~~

Information on instrumental and normal vaginal delivery was obtained from the South Australian Perinatal Statistics Collection and included all births in South Australia from 1999 to 2008. Perinatal information is gathered from the Supplemental Birth Record (SBR), which includes information on obstetric history, current pregnancy and birth information. Only singleton pregnancies with vertex presentations were included. In order to minimize confounding, infants with suspected foetal distress, those born via caesarean sections, low birth weight, prematurity, and suspected intrauterine growth restrictions were excluded.

Neurodevelopment was measured by NAPLAN test scores provided by the South Australian Department for Education and Child Development. The test is administered to all children attending grade 3, usually around 8 years of age, and covers five core domains: reading, writing, spelling, grammar, and numeracy. Each category is scored from 0-1,000, with expected scores at this age falling between the high 300s and low 400s. These scores are also grouped into broad proficiency bands of 1-7, with band 1 being the lowest and band 7 the highest. For children in grade 3. the NMS is set at band 2. Children who perform at or below the NMS often require additional classroom support due to low numeracy and literacy skills for their grade. In this study, the NAPLAN results are thus dichotomised into children performing at or below the NMS (≤ band 2) and those above it (bands 3 – 7).

The perinatal and NAPLAN datasets were linked via a unique linkage key. Linkage keys were generated by an independent linkage agency using a probabilistic algorithm that matches individuals across datasets using basic identifiers only (name, address, date of birth, gender). Clerical review and quality assurance checks were performed to minimize linkage errors. The linkage agency supplied unique linkage keys to the data custodians, who then provided data to us in a de-identified format.

We considered the following variables as potential confounding factors: maternal age, ethnicity (Caucasian, Aboriginal/Torres Strait Islander, Asian, other), having a partner (yes/no), socioeconomic disadvantage (using the Index of Relative Socioeconomic Advantage and Disadvantage, IRSAD[11]), geographic remoteness and isolation (measured using the Australian Remoteness Index for Areas, ARIA[12]), maternal smoking in the second half of pregnancy (yes/no), primary type of obstetric care

(hospital-based, private obstetrician, general practitioner, midwife, other), number of antenatal visits (≤7, 8-12, ≥13), gestational age at birth, birth weight for gestational age z-scores (calculated from recently published Australian norms[13]), infant sex, and pregnancy complications as an indicator of maternal health (diabetes (yes/no), hypertension (yes/no), maternal asthma (yes/no)). These data were primarily extracted from the SBR. However, when available, information on maternal age, socioeconomic disadvantage, remoteness and sex was also obtained from the Birth Registry database provided by the SA Births Registry, if the SBR was incomplete.

We calculated the average treatment effect (ATE) of forceps and ventouse deliveries compared with normal vaginal deliveries (reference) on whether a child met the NMS on the NAPLAN tests. The ATE was calculated by augmented inverse probability weighting (AIPW) using the effects command in Stata (SE version 14.0, Texas, USA). The AIPW method models the exposure, given a set of covariates, and generates an inverse probability of treatment (IPT) weight. The parameter estimates are used to calculate predicted outcomes for each individual under each exposure (only one of which is observed). For example, among forceps deliveries, (1) the IPT-weighted predicted outcome is subtracted from the IPT-weighted observed outcome, and (2) the predicted outcome under vaginal delivery is calculated. Then, the ATE is calculated from the means of all observed and predicted outcomes. For dichotomous outcomes of NAPLAN, the ATE provides the population proportion of children performing ≤NMS on each NAPLAN domain.

We conducted exploratory analyses to assess the potential for selection bias. *A priori*, our main analysis intended to focus on healthy infants at birth (singleton, term,

normal birthweight babies with vertex presentation and without suspected foetal distress) in order to address confounding. For example, suspected foetal distress is likely to be linked to higher risk of instrumental delivery and to poorer NAPLAN scores. However, this process may result in proportionally more infants being removed from the instrumental delivery groups compared with vaginal births, thereby leaving in the instrumental delivery groups the infants with better NAPLAN outcomes. Therefore, we re-conducted the analysis using all available data (whole population), then progressively removing subsamples (multiples, then non-vertex presentations, then preterms etc), and examining changes in effect estimates.

RESULTS

The flow of the participants within this study is shown in **Figure 1**. In total, 150,464 vertex singleton births were identified from 1999-2008 in South Australia, with data on 93,268 available after removing ineligible births. Year 3 NAPLAN results were available for 101,522 children. Of these, 47,552 were successfully linked. Non-linkage is in part due to the timing of the NAPLAN as only children in the perinatal database who were ~8 years old and attended grade 3 between 2008 to 2012 at a public school can be successfully linked.

The perinatal and sociodemographic characteristics of the mother and child are shown in **Table 1**. Compared with instrumental deliveries, mothers who had normal vaginal deliveries were more likely to be smokers in second half of pregnancy, have fewer antenatal visits, be living in a more disadvantaged area, be less likely to use private health care insurance, and less likely to be in the work force, although many of these differences are small. Infants born by instrumental deliveries were more likely to

undergo a prolonged labour and to require resuscitation at birth, although 5 minute APGAR scores were similar.

Table 2 contains the school achievement data according to mode of delivery. Across all NAPLAN domains, 12-21% of children from vaginal births perform at or below the NMS, compared with 8-17% for forceps and 9-17% for ventouse. These differences in poor NAPLAN performance were attenuated in the aipw analyses, where point estimates indicate performing at or below the NMS was 1-4% lower for babies born by forceps and ventouse, compared with vaginal deliveries.

Table 3 illustrates that within subgroups determined *a priori*, this risk for performing at or below the NMS remained 1-4% lower for babies born of instrumental delivery compared with normal vaginal delivered babies.

We conducted exploratory analyses to investigate the potential for selection bias. Online Supplementary **Table S1** shows the effect our inclusion criteria of singleton births, vertex presentations, ≥ 37 weeks gestational age, healthy birth weight, and no foetal distress, on performing ≤ NMS on the NAPLAN. Overall, the risk ratio and risk differences for forceps- and ventouse-delivered babies compared to normal vaginal delivered babies remained similar despite subsequent removal of infants not fitting our initial study inclusion criteria.

DISCUSSION

Using NAPLAN scores at eight years of age as a measure of school performance and thus a gauge for neurodevelopment, we conducted a long-term population-based study comparing NAPLAN results of children born of normal vaginal and instrumental deliveries. We had hypothesised that the increase in complications that led to an instrumental delivery or foetal head injury that may occur during some instrumental deliveries, would result in poorer schooling outcomes. However, we found no evidence to support this hypothesis and it is reassuring that the use of instrumental delivery is not associated with increased neurodevelopmental complications at 8 years of age.

As roughly one in ten births in Australia are by vaginal instrumental delivery, it is imperative to determine if there are long-term effects on child development. In trying to answer this, we have used a study design that has minimised selection bias. Furthermore, reporting bias is unlikely as data collection was performed by health professionals and teachers independently. The strength of this study is further enhanced by using aipw analyses to balance a broad range of sociodemographic and medical factors which may confound the association between instrumental delivery and child development.

However, the use of standardised test scores to measure performance is not perfect [14]. Our reliance on NAPLAN test scores as an indicator of neurodevelopment may therefore not be sensitive enough to detect subtle delays in developments or across other developmental domains. Moreover, with a combined total of 12,483 instrumental deliveries between 1999 and 2008, this study may not be sensitive enough to detect outcomes associated with rare complications of operative delivery,

the incidence of some of which are in the vicinity of between 1 in 1,000 to 1 in 10,000[5]. Thirdly, it is well documented that neurodevelopment and brain maturation continues well into adulthood[15]. It is thus possible that any detrimental effects from instrumental delivery have yet to manifest by the age of 8 years. Schizophrenia for example, an adult onset disease, has been noted to occur more commonly in those with a history of obstetrics complications [16,17]. Finally, our methodology may miss children with severe developmental impairments as they may not be attending school and therefore will not be included in the NAPLAN.

It has long been suspected that there may be long-term neurodevelopmental consequences from foetal injuries sustained during operative vaginal delivery. However, the evidence to confirm this is lacking. There have been studies that analysed the outcome of children born of instrumental deliveries at ages of 9 months up to 5 years [9,18,19]. Other studies have involved much smaller sample sizes (n's range from 71-295) but longer duration of follow-up to age 10 years and young adulthood [20,21]. Although the results from these studies also suggest that there are no detectable long-term adverse effects with instrumental delivery, our study is unique due to the large numbers, duration of follow-up, as well as the direct comparison between instrumental delivery and normal vaginal delivery. The process of excluding premature birth, intrauterine growth restriction, and foetal distress etc. was intended to reduce confounding but could have increased the potential for selection bias. This is because foetuses at imminent threat or with known risk factors for poor school outcomes would have been more likely to be born by instrumental delivery, leaving in the instrumental delivery groups the children who were more likely to perform better at school. However, our exploratory analyses (Online Table S1), provides little

evidence for results being due to selection bias. Likewise, our exploratory analyses indicate the findings are consistent even when looking among the healthiest infants at birth (APGAR ≥9), mothers free of diabetes and hypertension, and in the absence of prolonged labour (>18 hours). Like most observational studies, the findings are at risk of bias due to unmeasured confounding. While we have tried to balance confounding through the aipw analyses, we are unable to adjust for maternal BMI, duration of labour and accoucheur as these data were not available in our data. Adjustment for these factors could further reduce their possible confounding effects, and this is the reason for our conservative interpretation of the effect estimates. These are also important factors to investigate in future research.

In conclusion, we found that instrumental vaginal delivery has no negative effect on children's school performance at eight years of age.

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