

Suggested Focus for Research in the IACC Plan: Obstetric complications

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Summary

Autism cannot be identified in newborn babies, though genetic and prenatal predispositions are considered important. There is good reason to question whether obstetric procedures can cause injury that will only appear later in childhood. Respiratory depression at birth affects 5 to 6 infants per 1000, and is regarded to be a low number, but autism at the same prevalence (1 in 150) is shocking. Many children who develop autism suffered respiratory depression at birth. For example Glasson et al. (2004) reported that children who later developed autism were more likely to have taken more than one minute before onset of respiration at birth.

Until about 20 years ago obstetric teaching was to leave the umbilical cord intact until breathing was established. Now the published protocol is to clamp the cord immediately after delivery. How many prospective parents know anything about this? How many prospective parents understand that placental circulation continues after birth, and should not be terminated before the baby's lungs have taken over the function of respiration? Banking of umbilical cord blood requires termination of postnatal placental circulation if any significant amount of blood is to be collected.

The 5 to 6 per 1000 infants who develop respiratory depression are at risk for ischemic impairment of brainstem nuclei. The midbrain auditory nuclei (the inferior colliculi) are most susceptible to damage. Damage of the inferior colliculi has been observed in infants who died in early infancy. Gilles (1963) pointed out that lesions in the brains of human infants are identical to those found in monkeys subjected to asphyxia at birth; and Gilles suggested that aphasia in childhood might be the result of injury to the inferior colliculi.

Evidence from several case reports has revealed that injury to the inferior colliculi results in loss of the ability to comprehend spoken language. How much more serious such an injury would be for an infant, and in further experiments with monkeys, maturation of the brain did not follow a normal course following asphyxia at birth. Is neural plasticity a matter of wishful thinking?

A lapse in respiration at birth impairs the blood-brain barrier (BBB) first. This better explains the entry of bilirubin into vulnerable subcortical nuclei than direct toxicity of bilirubin. Likewise, injury caused by neonatal vaccinations can be better understood as entry across a compromised blood-brain barrier than as direct toxicity of vaccine components.

Itemized points

1. Autism cannot be identified in newborn babies.
2. Can obstetric procedures cause injury that will only appear later in childhood? [1-6]
3. Is umbilical cord blood banking safe? [7-10]
4. Placental circulation continues after birth and should not be terminated before the baby's lungs have taken over the function of respiration. [11-61]
5. The obstetric clamp was introduced in 1912, with explicit instruction to wait for pulsations of the umbilical cord to cease before applying the clamp. [62]
6. Until about 20 years ago obstetric teaching was to leave the umbilical cord intact until breathing was established. [63-126]
7. Respiratory depression at birth affects 5 to 6 infants per 1000, and is regarded to be a low number, but autism at the same prevalence (1 in 150) is shocking. [127-132]
8. Many children with autism suffered respiratory depression at birth. [133-155]
9. Symmetric bilateral damage of brainstem nuclei was found in newborn monkeys subjected to asphyxia, most prominent in the auditory pathway. [101, 114-116]
10. Symmetric bilateral damage of brainstem nuclei have been reported in human infants, also most prominent in the auditory pathway. [156-165]
11. Symmetric bilateral damage of brainstem nuclei is caused by toxic substances. [166-178]
12. Maturation of the brain in monkeys subjected to asphyxia at birth was not normal, and maturational abnormalities in autism are similar. [114, 179-181]
13. Kernicterus, like autism, is also now more prevalent, and results from disruption of the blood-brain barrier (BBB) plus bilirubin or other toxic substance. [182-185]
14. Could autism be a variant of kernicterus? I have posted this possibility at:
<http://www.conradsimon.org/Kernicterus2008.pdf>
15. Integrity of the auditory system is essential for normal language development. See:
<http://www.inferiorcolliculus.org/files/IACCMay12Comment.pdf>

REFERENCES

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REFERENCES, with notes, quotes, and illustrations

(From the bibliography of a work in progress – see www.conradsimon.org)

Current delivery room protocol – textbook instruction adopted in the 1980s

1. Hibbard, BM. Principles of Obstetrics. London; Boston: Butterworths, 1988.
"Apgar scores are recorded at 1 minute and again at 5 minutes, timing the observations accurately (see chapter 43, Table 43.1). Also the time to first breath and time to the establishment of regular respirations are recorded."
"Permanent cord clamps or ligatures (Figure 26.27) or special bands are applied to the umbilical cord as soon as possible after birth..." [p470]
"...As soon as possible after suctioning, the cord is clamped..."
"... consequences of a significant shift [of blood volume] toward the infant include polycythemia, circulatory volume overload, and hyperbilirubinemia, and these generally outweigh any potential advantage of augmenting the infant's iron reserve..." [p301, citing Cunningham et al., Williams Obstetrics, 18th ed.]
2. McGregor Kelly, J. General Care (chapt 22) in Avery GB, Fletcher MA, MacDonald MG, eds . Neonatology, Pathophysiology and Management of the Newborn, Fourth Edition. J.B. Lippincott Company, Philadelphia, 1994.
3. Cunningham FG, MacDonald PC, Gant NF, Leveno KJ, Gilstrap LC, Hankins GDV, Clark SL, Williams JW, (1997) Williams Obstetrics, Twentieth Edition. Stamford, Conn: Appleton & Lange, pp 336-337.
"Although the theoretical risk of circulatory overloading from gross hypervolemia is formidable, especially in preterm and growth-retarded infants, addition of placental blood to the otherwise normal infant's circulation ordinarily does not cause difficulty. Our policy is to clamp the cord after first thoroughly clearing the infant's airway, all of which usually takes about 30 seconds."
4. Turrentine, *Clinical Protocols in Obstetrics and Gynecology, Second Edition*, 2003.
 - (1) Doubly clamp cord segment (10-20 cm) immediately after birth in all deliveries, and place on table.
 - (2) pH and acid-base determinations indicated for:
 - prematurity
 - meconium
 - nuchal cord
 - low Apgar scores (< 7 at 5 minutes)
 - abnormal antepartum fetal heart tracing
 - any serious problem with delivery or neonate's condition

- (3) If unable to obtain cord specimen, aspirate artery on chorionic surface of placenta
 - (4) Discard cord segment if 5 minute Apgar score satisfactory and newborn stable/vigorous
5. Cunningham FG, Hauth JC, Leveno KJ, Gilstrap L III, Bloom SL, Wenstrom KD, eds, Williams Obstetrics - Twenty-second edition, New York: McGraw-Hill Medical Publishing Division, 2005.
- "... Our policy is to clamp the cord after first thoroughly clearing the airway, all of which usually requires about 30 seconds."
6. ACOG Committee on Obstetric Practice. ACOG Committee Opinion No. 348, November 2006: Umbilical cord blood gas and acid-base analysis. *Obstet Gynecol.* 2006 Nov;108(5):1319-22.

"Immediately after the delivery of the neonate, a segment of umbilical cord should be double-clamped, divided, and placed on the delivery table pending assignment of the 5-minute Apgar score. Values from the umbilical cord artery provide the most accurate information regarding fetal and newborn acid-base status. A clamped segment of cord is stable for pH and blood gas assessment for at least 60 minutes, and a cord blood sample in a syringe flushed with heparin is stable for up to 60 minutes (13, 14). If the 5-minute Apgar score is satisfactory and the infant appears stable and vigorous, the segment of umbilical cord can be discarded." [p1321]

Umbilical cord blood banking interrupts postnatal blood flow to/from the placenta

7. Dunn PM. Banking umbilical cord blood. *Lancet.* 1992 Aug 1;340(8814):309.
- "The HUC [umbilical cord blood] belongs to the baby, at least until adaptation to extrauterine life has taken place and umbilical pulsation has ceased. It is unethical to rely on permission obtained in advance from the mother to take the blood unless the critical importance of the transitional fetoplacental circulation is not only fully explained to her but also is defended in practice by the birth attendants. Unfortunately, in many parts of the world the importance of perinatal fetoplacental haemodynamics is poorly understood, as shown by the arbitrary way in which the cord is often triple-clamped at birth to obtain arterial and venous samples for blood gas and acid-base studies. This practice not only abruptly interrupts the umbilical circulation but may also deprive the newly born infant of an amount of blood equivalent to at least a third of its normal circulating volume." [p309]
8. Díaz-Rossello JL. Early umbilical cord clamping and cord-blood banking. *Lancet.* 2006 Sep 2;368(9538):840.

“Although there is strong evidence of its adverse effects, and no evidence of its benefits, early clamping is a common practice in modern obstetrics, especially with respect to the harvest of neonatal blood for cord blood banking.”

“...Quality standards for cord blood collection are based on ensuring that the largest volume of neonatal blood is retained in the placenta and umbilical cord, which involves clamping the cord as early and as close to the neonate as possible. If complete physiological redistribution of blood from the placenta to the infant’s body is allowed to take place, the cord becomes flaccid and pulseless, and the natural residual placental blood volume is insufficient for banking.”

“I suggest that the timing (in seconds) of cord clamping should be recorded at every birth, and that cord-blood donors should have a special haematological follow up.” [p840]

9. Royal College of Obstetricians and Gynaecologists. Scientific Advisory Committee opinion paper 2: umbilical cord blood banking. London: Royal College of Obstetricians and Gynaecologists, 2006.
http://www.rcog.org.uk/resources/public/pdf/cord_blood_parent_info.pdf
(accessed June 20, 2008)

“Some evidence indicates that immediate cord clamping may be harmful to babies. However, delaying cord clamping can prevent a successful cord blood collection.” [p5]

10. ACOG Committee on Obstetric Practice; Committee on Genetics. ACOG committee opinion number 399, February 2008: umbilical cord blood banking. *Obstet Gynecol.* 2008 Feb;111(2 Pt 1):475-7.

“The collection should not alter routine practice for the timing of umbilical cord clamping.” [p476]

But see cord clamping protocol stated in 2006 above [6]. Hopefully a change in the protocol is forthcoming.

Accumulating evidence of error – why are any more randomized controlled trials needed?

11. Peltonen T. Placental transfusion--advantage and disadvantage. *Eur J Pediatr.* 1981 Oct;137(2):141-6.
12. Künzel W. [Cord clamping at birth - considerations for choosing the right time (author's transl)] *Z Geburtshilfe Perinatol.* 1982 Apr-May;186(2):59-64. German.
13. Hohmann M. [Early or late cord clamping? A question of optimal time] *Wien Klin Wochenschr.* 1985 May 24;97(11):497-500. German.

14. Hofmeyr GJ, Bolton KD, Bowen DC, Govan JJ. Periventricular/intraventricular haemorrhage and umbilical cord clamping. Findings and hypothesis. *S Afr Med J*. 1988 Jan 23;73(2):104-6.
15. Hofmeyr GJ, Bex PJ, Skapinker R, Delahunt T. Hasty clamping of the umbilical cord may initiate neonatal intraventricular hemorrhage. *Med Hypotheses*. 1989 May;29(1):5-6.
16. [No authors listed] A study of the relationship between the delivery to cord clamping interval and the time of cord separation. Oxford Midwives Research Group. *Midwifery*. 1991 Dec;7(4):167-76.
17. Linderkamp O, Nelle M, Kraus M, Zilow EP. The effect of early and late cord-clamping on blood viscosity and other hemorheological parameters in full-term neonates. *Acta Paediatr*. 1992 Oct;81(10):745-50.
18. Kinmond S, Aitchison TC, Holland BM, Jones JG, Turner TL, Wardrop CA. Umbilical cord clamping and preterm infants: a randomised trial. *BMJ*. 1993 Jan 16;306(6871):172-5.
19. Grajeda R, Pérez-Escamilla R, Dewey KG. Delayed clamping of the umbilical cord improves hematologic status of Guatemalan infants at 2 mo of age. *Am J Clin Nutr*. 1997 Feb;65(2):425-31.
20. McDonnell M, Henderson-Smart DJ. Delayed umbilical cord clamping in preterm infants: a feasibility study. *J Paediatr Child Health*. 1997 Aug;33(4):308-10.
21. Papagno L. Umbilical cord clamping. An analysis of a usual neonatological conduct. *Acta Physiol Pharmacol Ther Latinoam*. 1998;48(4):224-7.
22. Morley GM. Cord closure: Can hasty clamping injure the newborn? *OBG Management*, July 1998: 29-36.
23. Mercer JS, Nelson CC, Skovgaard RL. Umbilical cord clamping: beliefs and practices of American nurse-midwives. *J Midwifery Womens Health*. 2000 Jan-Feb;45(1):58-66.
24. Ibrahim HM, Krouskop RW, Lewis DF, Dhanireddy R. Placental transfusion: umbilical cord clamping and preterm infants. *J Perinatol*. 2000 Sep;20(6):351-4.
25. Rabe H, Wacker A, Hülkamp G, Hörnig-Franz I, Schulze-Everding A, Harms E, Cirkel U, Louwen F, Witteler R, Schneider HP. A randomised controlled trial of delayed cord clamping in very low birth weight preterm infants. *Eur J Pediatr*. 2000 Oct;159(10):775-7.
26. Mercer JS. Current best evidence: a review of the literature on umbilical cord clamping. *J Midwifery Womens Health*. 2001 Nov-Dec;46(6):402-14.

27. Gupta R, Ramji S. Effect of delayed cord clamping on iron stores in infants born to anemic mothers: a randomized controlled trial. *Indian Pediatr.* 2002 Feb;39(2):130-5.
28. Buckley S. A natural approach to the third stage of labour. A look at early cord clamping, cord blood harvesting, and other medical interference. *Midwifery Today Int Midwife.* 2001 Fall;(59):33-6.
29. Mercer JS, McGrath MM, Hensman A, Silver H, Oh W. Immediate and delayed cord clamping in infants born between 24 and 32 weeks: a pilot randomized controlled trial. *J Perinatol.* 2003 Sep;23(6):466-72.
30. van Rheenen P, Brabin BJ. Late umbilical cord-clamping as an intervention for reducing iron deficiency anaemia in term infants in developing and industrialised countries: a systematic review. *Ann Trop Paediatr.* 2004 Mar;24(1):3-16.
31. Rabe H, Reynolds G, Diaz-Rossello J. Early versus delayed umbilical cord clamping in preterm infants. *Cochrane Database Syst Rev.* 2004 Oct 18;(4):CD003248.
32. Hutchon DJ. Epidemiology of preterm birth: delayed cord clamping used to be taught and practised. *BMJ.* 2004 Nov 27;329(7477):1287; author reply 1287.
33. Philip AGS, Saigal S. When should we clamp the umbilical cord? *Neoreviews.* 2004; 5: 142-154. Online at: <http://neoreviews.aappublications.org/cgi/reprint/5/4/e142> (accessed 6/28/08).
34. Mercer JS, Skovgaard RL, Peareara-Eaves J, Bowman TA. Nuchal cord management and nurse-midwifery practice. *J Midwifery Womens Health.* 2005 Sep-Oct;50(5):373-9.
35. Aladangady N, McHugh S, Aitchison TC, Wardrop CA, Holland BM. Infants' blood volume in a controlled trial of placental transfusion at preterm delivery. *Pediatrics.* 2006 Jan;117(1):93-8.
36. Ceriani Cernadas JM, Carroli G, Pellegrini L, Otaño L, Ferreira M, Ricci C, Casas O, Giordano D, Lardizábal J. The effect of timing of cord clamping on neonatal venous hematocrit values and clinical outcome at term: a randomized, controlled trial. *Pediatrics.* 2006 Apr;117(4):e779-86.
37. Mercer JS, Vohr BR, McGrath MM, Padbury JF, Wallach M, Oh W. Delayed cord clamping in very preterm infants reduces the incidence of intraventricular hemorrhage and late-onset sepsis: a randomized, controlled trial. *Pediatrics.* 2006 Apr;117(4):1235-42.
38. Philip AG. Delayed cord clamping in preterm infants. *Pediatrics.* 2006 Apr;117(4):1434-5.
39. Chaparro CM, Neufeld LM, Tena Alavez G, Eguia-Líz Cedillo R, Dewey KG. Effect of timing of umbilical cord clamping on iron status in Mexican infants: a randomised controlled trial. *Lancet.* 2006 Jun 17;367(9527):1997-2004.

40. Mercer J, Erickson-Owens D. Delayed cord clamping increases infants' iron stores. *Lancet*. 2006 Jun 17;367(9527):1956-8.
41. van Rheenen PF, Gruschke S, Brabin BJ. Delayed umbilical cord clamping for reducing anaemia in low birthweight infants: implications for developing countries. *Ann Trop Paediatr*. 2006 Sep;26(3):157-67.
42. Levy T, Blickstein I. Timing of cord clamping revisited. *J Perinat Med*. 2006;34(4):293-7.
43. van Rheenen PF, Brabin BJ. Effect of timing of cord clamping on neonatal venous hematocrit values and clinical outcome at term: a randomized, controlled trial. *Pediatrics*. 2006 Sep;118(3):1317-8; author reply 1318-9.
44. Hutchon D, Ononeze B. Preterm birth: effect of corticosteroids or immediate cord clamping? *PLoS Med*. 2006 Oct;3(10):e462.
45. van Rheenen PF, Brabin BJ. A practical approach to timing cord clamping in resource poor settings. *BMJ*. 2006 Nov 4;333(7575):954-8.
46. Hutchon DJ. Delayed cord clamping may also be beneficial in rich settings. *BMJ*. 2006 Nov 18;333(7577):1073.
47. Hosono S, Mugishima H, Fujita H, Hosono A, Minato M, Okada T, Takahashi S, Harada K. Umbilical cord milking reduces the need for red cell transfusions and improves neonatal adaptation in infants born at less than 29 weeks' gestation: a randomised controlled trial. *Arch Dis Child Fetal Neonatal Ed*. 2008 Jan;93(1):F14-9.
48. Ultee CA, van der Deure J, Swart J, Lasham C, van Baar AL. Delayed cord clamping in preterm infants delivered at 34-36 weeks' gestation: a randomised controlled trial. *Arch Dis Child Fetal Neonatal Ed*. 2008 Jan;93(1):F20-3.
49. Baenziger O, Stolkin F, Keel M, von Siebenthal K, Fauchere JC, Das Kundu S, Dietz V, Bucher HU, Wolf M. The influence of the timing of cord clamping on postnatal cerebral oxygenation in preterm neonates: a randomized, controlled trial. *Pediatrics*. 2007 Mar;119(3):455-9.
50. Hutton EK, Hassan ES. Late vs early clamping of the umbilical cord in full-term neonates: systematic review and meta-analysis of controlled trials. *JAMA*. 2007 Mar 21;297(11):1241-52.
51. van Rheenen P, de Moor L, Eschbach S, de Groot H, Brabin B. Delayed cord clamping and haemoglobin levels in infancy: a randomised controlled trial in term babies. *Trop Med Int Health*. 2007 May;12(5):603-16.
52. Mercer JS, Erickson-Owens DA, Graves B, Haley MM. Evidence-based practices for the fetal to newborn transition. *J Midwifery Womens Health*. 2007 May-Jun;52(3):262-72.

53. Kugelman A, Borenstein-Levin L, Riskin A, Chistyakov I, Ohel G, Gonen R, Bader D. Immediate versus delayed umbilical cord clamping in premature neonates born < 35 weeks: a prospective, randomized, controlled study. *Am J Perinatol*. 2007 May;24(5):307-15.
54. Dewey KG, Chaparro CM. Session 4: Mineral metabolism and body composition iron status of breast-fed infants. *Proc Nutr Soc*. 2007 Aug;66(3):412-22.
55. Weeks A Umbilical cord clamping after birth. *BMJ*. 2007 Aug 18;335(7615):312-3.
56. Rabe H, Reynolds G, Diaz-Rossello J. A systematic review and meta-analysis of a brief delay in clamping the umbilical cord of preterm infants. *Neonatology*. 2008;93(2):138-44.
57. Chaparro CM, Fornes R, Neufeld LM, Tena Alavez G, Eguía-Líz Cedillo R, Dewey KG. Early umbilical cord clamping contributes to elevated blood lead levels among infants with higher lead exposure. *J Pediatr*. 2007 Nov;151(5):506-12.
58. Strauss RG, Mock DM, Johnson KJ, Cress GA, Burmeister LF, Zimmerman MB, Bell EF, Rijhsinghani A. A randomized clinical trial comparing immediate versus delayed clamping of the umbilical cord in preterm infants: short-term clinical and laboratory endpoints. *Transfusion*. 2008 Apr;48(4):658-65.
59. Wiberg N, Källén K, Olofsson P. Delayed umbilical cord clamping at birth has effects on arterial and venous blood gases and lactate concentrations. *BJOG*. 2008 May;115(6):697-703.
60. McDonald SJ, Middleton P. Effect of timing of umbilical cord clamping of term infants on maternal and neonatal outcomes. *Cochrane Database Syst Rev*. 2008 Apr 16;(2):CD004074.
61. Wyllie J, Niermeyer S. The role of resuscitation drugs and placental transfusion in the delivery room management of newborn infants. *Semin Fetal Neonatal Med*. 2008 May 26 [Epub ahead of print]

Introduction of the obstetric clamp (1912)

62. Wechsler BB. Umbilical clamp. *Am J Obstet Dis Women Child* 1912; 60:85-6.

"I desire to present to the profession a little device for use on the cord instead of the usual ligature." [p85].

Wechsler reported that on a recent visit to Vienna, he had witnessed the method of clamping and dressing the umbilical cord without ligature in the Schauta Clinic. Wechsler's clamp is pictured and noted to be smaller than the "ordinary Hemostat" used in Vienna. Rationale for use of a clamp was that it lessens the danger of infection. Its use was described as follows:

"Clamping the cord is accomplished in the following way:

1. Wait until pulsation has ceased;

2. Clamp cord about one inch from umbilicus;
3. Cut cord even with clamp.

The infant is then removed by the nurses and the clamp allowed to remain on stump of cord for fifteen minutes, or about the time the placenta has been expelled then the clamp is ready to taken off." [p86]

Childbirth tradition

Early understanding of fetal circulation, respiration, and neonatal transition

63. Harvey, William. *Anatomical exercitations concerning the generation of living creatures to which are added particular discourses of births and of conceptions, &c.* London : Printed by James Young, for Octavian Pulleyn, and are to be sold at his shop at the sign of the Rose in St. Pauls Church-yard, 1653. From Early English Books Online, <http://eebo.chadwyck.com/> (accessed 6/28/08).

"Moreover, it is a sure way to know whether the Infant that sticketh in the birth be alive, or not, by the pulsation of the Vmbilical Arteries. But most certain it is, that those Arteries are not moved by the virtue or operation of the Mothers, but of his own proper Heart: For they keep a distinct time and pawze, from the Mothers pulse: which is easily experimented, if you lay one hand upon the Mothers wrest, and the other on the Infants Navel-string. Nay in a Casarean Section, when the Embryo's have been yet involved in the membrane called Chorion, I have oftentimes found (even when the Mother was extinct, and stiffe almost with cold) the Vmbilical Arteries beating, and the Foetus himself lusty."

64. White C (1773) *A Treatise on the Management of Pregnant and Lying-In Women.* Canton, MA: Science History Publications, 1987. Available from <http://www.shpusa.com/bkindex.html> (accessed 6/28/08)

"Can it possibly be supposed that this important event, this great change which takes place in the lungs, the heart, and the liver, from the state of a foetus, kept alive by the umbilical cord, to that state when life cannot be carried on without respiration, whereby the lungs must be fully expanded with air, and the whole mass of blood instead of one fourth part be circulated through them, the ductus venosus, foramen ovale, ductus arteriosus, and the umbilical arteries and vein must all be closed, and the mode of circulation in the principal vessels entirely altered - Is it possible that this wonderful alteration in the human machine should be properly brought about in one instant of time, and at the will of a by-stander?" [p45]

65. Darwin, E *Zoonomia; or, The Laws of Organic Life, Vol 1, Section XXXVIII.* New York: T&J Swords, Faculty of Physic of Columbia College,1796.

"The placenta is an organ for the purpose of giving due oxygenation to the blood of the fetus; which is more necessary, or at least more frequently necessary, than even the supply of food." [p350]

66. Darwin, E. *Zoonomia, or the laws of organic life, third Edition*. Vol. III. London, J. Johnson, 1801.

Tying of the cord too soon has been a longstanding problem as was recognized by White (1773) above, and Erasmus Darwin (grandfather of Charles) who stated:

"Another thing very injurious to the child, is the tying and cutting of the navel string too soon; which should always be left till the child has not only repeatedly breathed but till all pulsation in the cord ceases. As otherwise the child is much weaker than it ought to be, a portion of the blood being left in the placenta, which ought to have been in the child." [p321]

Textbook instruction on ligation of the cord (to the early 20th century)

Traditional textbooks of midwifery and obstetrics gave explicit instruction not to tie the cord until the infant was breathing, and that it was better to wait for pulsations to cease. Following are quotes from several texts, along with contemporary research findings and opinions:

67. Meigs C. Professor of Obstetrics and Diseases of Women and Children, Jefferson Medical College. *A Philadelphia Practice of Midwifery*, 1842

"The head is born: perhaps the cord is turned once, or even more than once around the child's neck, which it encircles so closely as to strangulate it. Let the loop be loosened to enable it to be cast off over the head. ... [or] by slipping it down over the shoulders. ... If this seems impossible, it should be left alone; and in the great majority of cases, it will not prevent the birth from taking place, after which the cord may be cast off. ... Should the child be detained by the tightness of the cord, as does rarely happen, ... the funis may be cut ... Under such a necessity as this, a due respect for one's own reputation should induce him to explain, to the bystanders, the reasons which rendered so considerable a departure from the ordinary practice so indispensable. I have known an accoucheur's capability called harshly into question upon this very point of practice. I have never felt it necessary to do it but once. ... The cord should not be cut until the pulsations have ceased."

68. Churchill F *On the Theory and Practice of Midwifery*. London: Henry Renshaw, 1850.

"After birth of the child, the pulsation ceases in about fifteen or twenty minutes, and that portion of the cord which remains attached to the

umbilicus dies, and gradually withers, until it falls off, in the majority of cases, on the fifth or sixth day." [p 91 #181 The umbilical cord, funis, or navel string].

"...in ordinary cases, if we find that the cord is twisted around the neck, all we need do is to draw down more of the cord, and either slip the loop over the head or shoulders. If we cannot do this, we must loosen the cord as much as we can, so as to prevent the strangulation of its vessels, and wait for the uterus to expel the child." [p 131]

"If the child be healthy, and not have suffered from pressure, &c. it will cry as soon as it is born, and when respiration is established, it may be separated from its mother..." [p 132]

69. Cazeaux P A Theoretical and Practical Treatise on Midwifery. Fifth American from the Seventh French Edition by Wm R Bullock, MD. Philadelphia: Lindsay and Blakiston, 1871.

"...the circulation existing between it [the child] and the placenta is observed to continue for some time... pulsations in the arteries gradually cease, commencing at their placental extremity; and some authors have advised this event to be waited for before cutting the cord..." [p. 406]

70. Lusk WT The Science and Art of Midwifery. New York: D Appleton and Company, 1882,

"Infants which have had the benefit of late ligation of the cord are red, vigorous, and active, whereas those in which the cord is tied early are apt to be pale and apathetic."

"1. The cord should not be tied until the child has breathed vigorously a few times. When there is no occasion for haste, it is safer to wait until the pulsations of the cord have ceased altogether.

2. Late ligation is not dangerous to the child. The child receives into its system only the amount of blood required to supply the needs created by the opening up of the pulmonary circulation." [pp214-215]

71. Jellet, Henry. A Manual of Midwifery for Students and Practitioners. New York: William Wood & Company, 1910.

"As soon as the child is born, its eyes are wiped, any mucus in the air passages is removed, and it is placed in a convenient position between the patient's legs. The cord is tied as soon as it has stopped pulsating, and the infant is then removed." [p350]

Introduction of the obstetric clamp (1912)

72. Wechsler BB. Umbilical clamp. Am J Obstet Dis Women Child 1912; 60:85-6. (see citation 62 above – the clamp was to be applied only after all pulsations in the cord had ceased).

Obstetric teaching and concurrent research papers (until the 1930s)

73. Williams JW. (1917) *Obstetrics: A Text-Book for the Use of Students and Practitioners*, Fourth Edition, New York: Appleton, 1917.
- "Immediately after its birth the child usually makes an inspiratory movement and then begins to cry. In such circumstances it should be placed between the patient's legs in such a manner to have the cord lax, and thus avoid traction upon it. "
- "Normally the cord should not be ligated until it has ceased to pulsate.."
- "I have always practiced late ligation of the cord and have seen no injurious effects following it, and therefore recommend its employment, unless some emergency arises which calls for earlier interference." [pp342-343]

More on use of a clamp (a decade after its introduction)

74. Ziegler CE. Additions to our obstetric armamentarium. Am J Obstet Gynecol 1922; 3:46-53.
- "The primary object of ligating or clamping the cord is, of course, to prevent hemorrhage; and while it is true that hemorrhage would rarely occur even were the cord not compressed, especially after the establishment of respiration, the fact is that hemorrhages have occurred and even with fatal termination. In fifteen years I have had two cases of secondary hemorrhage from the cord which were all but fatal. It is likely, therefore, that some form of compression will always be regarded as necessary."
75. Levy WE, discussant of Dicks JF. Treatment of the umbilical cord by short ligation and the use of a clamp. Am J Obstet Gynecol 1925 Nov; 10(5):706-8. Discussion pp739-40.
- "I am rather inclined to disagree with those who advocate the use of a clamp. To me the ligation of the cord is one of the simplest processes in obstetrics, and why complicate what is inherently simple? I quite agree that the cord should be tied as close as possible to the skin margin, but a piece of tape does that just as well as an instrument. The clamp crushes and macerates the tissues, and macerated tissue, as is well known, is prone to develop bacteria. This also holds true of the so-called milking of the cord, which frequently breaks down the outer surface and so favors the entrance of infection." [p740]

76. von Reuss, August Ritter. *The Diseases of the Newborn*. New York: William Wood & Co, 1921. (Vienna, January 1914)
- "... A compromise is usually adopted, in that the cord is not tied immediately after birth, nor does one wait till the expression of the placenta, but only until the cessation of pulsation in the cord, an average of five to ten minutes." [p419]
77. Willaims, JW. *Obstetrics: A Textbook for the use of Students and Practitioners*, Fifth enlarged and revised edition. D. Appleton and Company, New York, 1927
- "I have always practiced late ligation of the cord and have seen no injurious effects following it, and therefore recommend its employment, unless some emergency arises which calls for earlier interference..."
78. DeLee JB. *The Principles and Practice of Obstetrics*. Philadelphia, WB Saunders, Company, 1930.
- "Tying the cord. – After waiting until the pulsation in the exposed umbilical cord has perceptibly weakened or disappeared, the child is severed from its mother. Until the cord is severed the child is still part of its mother and has no legal existence... During the four or eight minutes while waiting to tie the cord the child obtains from 40 to 60 gm. Of the reserve blood of the placenta – a fact that was first shown by Budin. The blood is pressed into the child by the uttering contractions, and part is aspirated by the expanding chest. This extra blood the child needs in its first days of life, and observation has shown that such children lose less in weight and are less subject todisease..." [p330]
79. Baer JL, in Curtis AH, ed. *Obstetrics and Gynecology* (3 vols). Philadelphia & London: WB Saunders Company, 1933, Chapt XXIV – The conduct of normal labor pp 702-844.
- "In most clinics the cord is not tied until pulsation has ceased. This is based on the accepted fact that the delay provides the infant with an additional average of 60 to 90 cc of blood. With premature infants or twins, most of which are usually below the weights of average single infants, this additional blood is a distinct advantage. In full-term infants of normal size the advantage is more theoretical than real." [p828]
80. DeLee, Joseph B. *The Principles and Practice of Obstetrics*, Sixth Edition. Philadelphia and London: W.B. Saunders Company, 1936.
[earlier editions: 1913, '15, '18, '24, '28, '33 (6th) reprinted in '34 & '36]
- "After waiting until the pulsation in the exposed umbilical cord has perceptibly weakened or disappeared, the child is severed from its mother."
- "During the four or eight minutes while waiting to tie the cord the child obtains from 40 to 60 gm of the reserve blood of the placenta – a fact that

was first shown by Budin. The blood is pressed into the child by the uterine contractions, and part is aspirated by the expanding chest. This extra blood the child needs in its first days of life, and observation has shown that such children lose less in weight and are less subject to disease. It is an error, on the other hand, to force the blood of the placenta into the child by stripping the cord toward the child. This overloads its blood vessels, causes icterus, melena, even apoplexy ..." [p334]

81. Fitzgibbon, Gibbon. *Obstetrics*. Browne and Nolan Limited, Dublin, 1937.
"...If the infant has cried and has respired well for about five minutes, there is no advantage in leaving it attached any longer to the placenta. Its pulmonary circulation has been opened up and the pulmonary vessels filled with blood ..." [p128]
82. Frischkorn HB , Rucker MP. The relationship of the time of ligation of the cord to the red blood count of the infant. *Am J Ostet Gynecol* 1939; 38:592-594.
"If a cord be watched immediately after delivery the umbilical vessels can be seen to pulsate strongly throughout their entire length. In a varying length of time the pulsations cease in the more distal part and as this occurs the umbilical vessels collapse. This process of cessation of pulsation and collapse of the vessels proceeds toward the umbilicus until finally there is no pulsation even at the navel. The vessels are then entirely collapsed. If now the cord be tied and cut very little blood will escape from the placental end." [p 593]
83. Windle WF (1940) Round table discussion on anemias of infancy (from the proceedings of the tenth annual meeting of the American Academy of Pediatrics) *Journal of Pediatrics* 18:538-547.
"... The rather common practice of promptly clamping the cord at birth should be condemned. Of course, this will make it impossible to salvage placental blood for 'blood banks.' However, the collection of usable quantities of placental blood robs the newborn infant of blood which belongs to him and which he retrieves under natural conditions...
Immediate clamping of the cord is comparable to submitting the infant to a rather severe hemorrhage." [1, p546]
84. Read, Grantly Dick. *Childbirth Without Fear: The principles and practice of natural childbirth*. Harper & Brothers Publishers, New York and London, 1944.
"It is my custom to lift up the crying child, even before the cord is cut ..."
"Its first cry remains an indelible memory on the mind of a mother; it is the song which carried her upon its wings to an ecstasy mere man seems quite unable to comprehend." [p95]

Pulmonary oxygenation effects closure of the umbilical arteries

85. Spivack M. The anatomic peculiarities of the human umbilical cord and their clinical significance. *Am J Obstet Gynecol* 1946 Sep; 52(3):387-401.

"Oxygenation of the newborn's blood after establishment of its pulmonary respiration is the main factor in bringing about closure of the umbilical arteries...

...Experience since long ago has taught some clinicians that ligation of the cord is not paramount in the care of the stump." [1, p398]

86. Eisaman JR Jr., discussant of Ballentine GN. Delayed ligation of the umbilical cord. *The Pennsylvania Medical Journal* 1947, Apr; 50 (7):726-728.

"There seems to be undue haste in severing the umbilical cord immediately after the second stage of labor...

...This practice involves many poorly understood changes in neonatal physiology, i.e., closure of the ductus arteriosus and ductus venosus...

...Not long ago placental blood was recommended for transfusions. The volume so obtained was 125 to 250cc, providing immediate ligation of the cord was performed." [p728].

87. McCausland AM, Homes F, Schumann WR (1949) Management of cord and placental blood and its effect upon the newborn; part I. *California Medicine* 71(3):190-196.

McCausland et al. (1949) sent a questionnaire to 1,900 diplomates of the American Board of Obstetrics and Gynecology to determine the usual practice at that time of handling the umbilical cord at birth. Replies from almost every state numbered 1,198 and revealed that 497 (41.5%) clamped the cord immediately after birth, 400 clamped the cord within five minutes after birth, and only 191 waited for pulsations to cease. However, 455 practiced stripping of the cord.

McCausland et al. recommended stripping of the cord, especially for premature infants, whom they described as not only underdeveloped, but often in varying degrees of shock.

88. Eastman HJ. *Williams Obstetrics*, Tenth Edition, New York, Appleton-Century-Crofts, 1950.

"Whenever possible, clamping or ligating the umbilical cord should be deferred until its pulsations wane or, at least, for one or two minutes...

.... There has been a tendency of late, for a number of reasons, to ignore this precept. In the first place the widespread use of analgesic drugs in labor has resulted in a number of infants whose respiratory efforts are sluggish at birth and whom the obstetrician wishes to turn over immediately to an

assistant for aspiration of mucus, and if necessary, resuscitation. This readily leads to the habit of clamping all cords promptly." [pp397-398]

89. Landau DB, Goodrich HB, Francka WF, Burns FR Death of cesarean infants: a theory as to its cause and a method of prevention. *Journal of Pediatrics* 1950; 36:421-426.

"Usually at the time of cesarean section as soon as the uterus is opened the operator delivers the infant as rapidly as is consistent with the infant's safety. The cord is clamped and cut immediately and the infant is handed to the waiting assistant...

...This is in marked contrast to the procedure during normal or vaginal delivery. At this time the cord is not clamped and severed until pulsations have ceased."

90. Greenhill JP. *Principles and Practice of Obstetrics*; originally by Joseph B. DeLee, M.D., Tenth Edition. W.B. Saunders Company, Philadelphia and London, 1951.

"After waiting until the pulsation in the exposed umbilical cord has ceased, the child is severed from its mother."

"DeMarsh, Alt, Windle and Hillis [The effect of depriving the infant of its placental blood; on the blood picture during the first week of life. *JAMA* 1941; 116:2568-2573] showed that those infants whose cords were not clamped until the placenta had separated from the uterus had on average 0.556 million more erythrocytes per cubic millimeter and 2.6 gm more hemoglobin per 100cc during the first week than those whose cords were clamped immediately. These authors maintained that early clamping of the umbilical cord is equivalent to submitting the child to a hemorrhage at birth.

Wilson, Windle and Alt [Deprivation of placental blood as a cause of iron deficiency in infants. *Am J Dis Child* 1941; 62:320-327.] found that infants whose umbilical cords were clamped immediately after birth had a lower mean corpuscular hemoglobin at eight and ten months of age than those whose cords were clamped after the placenta began to descend into the vagina. It was suggested then that early clamping of the cord may lead to an iron deficiency during the first year of life."

"McCausland, Holmes and Schumann [Management of cord and placental blood and its effect upon the newborn; part I. *California Medicine* 1949; 71(3):190-196.] advise stripping the cord and placental blood into the infant because it is harmless if done gently and because term babies receive about 100cc of extra blood in this way. These authors claim that babies receiving this blood had higher erythrocyte counts, higher hemoglobin values, higher initial weights and less initial weight losses." [p.251]

From Apgar onward (and concurrent research)

91. Apgar V (1953) A proposal for a new method of evaluation of the newborn infant. *Current Researches in Anesthesia and Analgesia* 32:260-267. Online at: http://apgar.net/virginia/Apgar_Paper.html (accessed 6/28/08)

This was Apgar's first paper on scoring the condition of infants during the minutes following birth. Apgar attributed failure of an infant to breathe right away at birth as the result of too much anesthesia given the mother during childbirth, and she stated: "It is common for an infant to breathe once, but then become apneic for many minutes. A satisfactory cry is sometimes not established even when the infant leaves the delivery room"

But should any newborn leave the delivery room, or his connection to his mother before breathing is established?

In a report five years later, Apgar et al. (1958) reported that they clamped the cord within the first minute after birth to preserve the "sterile field" and to transfer the baby to neonatal specialists. See citation 148 below.

Meanwhile, many obstetricians continued to follow the instruction of textbooks to wait for pulsations of the cord to cease.

Research on expansion of the lungs at birth

92. Jäykkä S. A new theory concerning the mechanism of the initiation of respiration in the newborn; a preliminary report. *Acta Paediatr.* 1954 Sep;43(5):399-410.

Jäykkä proposed his theory that filling of the capillary bed surrounding the alveoli was the stimulus for initiating lung expansion and the first breath of the newborn.

1955 Greenhill's textbook review of evidence

93. Greenhill, JP *Obstetrics Eleventh Edition* WB Saunders Company, Philadelphia and London, 1955

"Immediately after the baby is delivered it should be held well below the level of the vulva for a few minutes or placed in a warm container the level of which is considerably below the mothers' buttocks (Fig 279). The purpose of keeping the baby at this level is to permit the blood in the placenta to get to the baby. Dieckmann and associates maintain that this procedure will add from 50 to 75 percent of the blood in the placenta and cord to the newborn child [Dieckmann, WJ, Forman JB, and Philips GW: *Effects of Intravenous Injections of Ergonovine and Solution of Posterior Pituitary Extract on the Postpartum Patient.* *Am. J. Obst. & Gynec* 60:655 (Sept) 1950].

If the placenta separates while waiting, expressing it from the uterus and holding it elevated for two or three minutes will accomplish the same

purpose. The cord is cut after about three minutes or after it collapses. If the baby is in a special container, it is left in until after the cord is cut. As soon as possible after delivery any mucus in the air passages must be removed with a soft rubber bulb or a tracheal catheter.

Tying the Cord. After waiting until the pulsation in the exposed cord has ceased, using dull scissors, the child is severed from its mother. With a piece of linen bobbin, coarse silk, rubber band or any sterile strong string, the cord is ligated close to the cutaneous margin of the umbilicus, making sure that there is no umbilical hernia which might allow a loop of intestine to be caught in the grasp of the ligature. It is important to leave as little as possible of the cord to be cast off except when a baby has erythroblastosis..."

"DeMarsh, Alt, Windle, and Hillis showed that infants whose cords were not clamped until the placenta had separated from the uterus had an average of 0.56 million more erythrocytes per cubic millimeter and 2.6 gm. More hemoglobin per 100 ml. during the first week than those whose cords were clamped immediately. These authors maintained that early clamping of the cord is equivalent to submitting the child to a hemorrhage at birth. Wilson, Windle and Alt found that infants whose umbilical cords were clamped immediately after birth had a lower mean corpuscular hemoglobin at 8 and 10 months of age than those whose cords were clamped after the placenta began to descend into the vagina. Thus early clamping of the cord may lead to an iron deficiency during the first year of life.

McCausland, Holmes and Schumann advise stripping the cord and placental blood into the infant because it is harmless if done gently and because term babies receive about 100 ml of extra blood in this way. Babies receiving this blood have higher erythrocyte counts, higher hemoglobin values, higher initial weights and less initial weight losses." [pp280-282]

"After waiting until the pulsation in the exposed cord has ceased, using dull scissors, the child is severed from its mother." [p281]

Citing the work of Landau et al. [Landau DB et al. J Pediat 36:421, April 1950.]:

"In attempting to account for the death of babies delivered by cesarean section, Landau and associates concluded that blood loss to the child incurred by immediate clamping of the cord amounted to 90 ml, a quantity of definite significance, especially in preterm infants. Improvement was noted in the condition of babies when drainage of blood from the placenta, after its removal, was facilitated by suspending it in a towel above the child for six to ten minutes or until the cord vessels collapsed." [p283]

Blood flow is found to be higher in the auditory system than anywhere else in the brain

94. Landau WM, Freygang WH, Rowland LP, Sokoloff L, Kety SS. The local circulation of the living brain; values in the unanesthetized and anesthetized cat. *Trans Am Neurol Assoc.* 1955-1956;(80th Meeting):125-9.

This was the first report on blood flow measurements using a radioactive tracer. That nuclei of the brainstem auditory pathway are the sites of highest blood flow came as a surprise, but also predicted the pattern of damage found by Ranck and Windle (1959) in monkeys subjected to asphyxia at birth.

Weight gain from placental transfusion

95. Gunther M. The transfer of blood between baby and placenta in the minutes after birth. *Lancet.* 1957 Jun 22;272(6982):1277-80.

Measurements of weight change at birth following placental transfusion. Gunther reconfirmed results of research from 1875 to 1930 published in French and German journals.

Human assisted delivery of thoroughbred foals and the convulsive foal syndrome

96. Mahaffey LW, Rossdale PD (1957) On the newborn infant's oxygen supply. *Lancet* 1957 Jul 13, ii:95.

Mahaffey and Rossdale (responding to the article above by Gunther) described a convulsive syndrome affecting about 2 percent of thoroughbred foals delivered with human assistance.

"For a considerable time we have been greatly concerned with the possibility that the syndromes are associated with very early severance of the umbilical cord."

"It seems more than a coincidence that, as far as we can verify, the syndromes do not occur in thoroughbred foals which are born unattended in open paddocks in Australia, but are well known in France and Italy, where the cord is always severed by attendants within seconds of birth. Further, in Europe the disease seems to be unknown in breeds of horses other than thoroughbreds and these generally foal without human 'interference.'

Other domestic species which give birth to their young alone, and 'naturally,' are similarly unaffected."

Transfer of placental blood to the alveolar capillaries opens the lungs

97. Jäykkä S. Capillary erection and lung expansion; an experimental study of the effect of liquid pressure applied to the capillary network of excised fetal lungs. *Acta Paediatr Suppl.* 1957 Jan;46(suppl 112):1-91.

Jäykkä provided evidence in support of the theory he proposed in 1954 that expansion of the lungs after birth results from fluid filling the capillary network surrounding the alveoli.

Textbooks continued to promote placental transfusion

98. Willson JR, Beecham CF, Forman I, Carrington ER. Obstetrics and Gynecology. The CV Mosby Company, St. Louis, 1958.

"The baby is held with its head downward for a few seconds while the cord is stripped from the introitus toward the infant several times. This adds 75 or more ml of blood, which would otherwise be discarded with the placenta, to the infant's vascular system." [p337]

"The blood in the fetal circulation is distributed between the vessels in the infant's body and those in the placenta ..."

"...At the end of the second trimester about half the total blood is in the placenta, but as the baby grows larger relatively more is contained in the infant itself. The blood volume of the newly born baby is only about 250 ml. Consequently as much as possible must be preserved. If clamping and ligation of the cord are delayed for several minutes after the baby is born, as much as 100 ml of blood will be transferred from the placenta to the baby. The same result can be obtained by stripping the cord from the vulva toward the infant repeatedly until no more blood enters the vessels from the placental end." [p373]

Apgar et al. promoted clamping of the cord within one minute after birth

99. Apgar V, Holaday DA, James LS, Weisbrot IM. Evaluation of the newborn infant – second report. JAMA 1958; 168(15):1985-9.

In 1958, Apgar (and her colleagues) wrote that scoring at one minute was done because this represented the time of most severe depression:

"In the Sloane Hospital the cord has been cut by this time, and the infant is in the hands of an individual other than the obstetrician. In many hospitals, such is not the case. Those obstetricians who practice slow delivery and delayed clamping of the cord until pulsations of the umbilical artery cease still have the infant in the sterile field. However, if the obstetrician is reminded of the passage of time by another observer, he may assign a score even though the cord is still attached," [p1987]

Thus the Apgar score devised over 50 years ago reflected the perceived need to remove the newborn from the "sterile field" for repair of the episiotomy, manage delivery of the placenta, and to give the infant to neonatal specialists, often for resuscitation.

Apgar et al. also wrote in the 1958 paper:

“All infants with a score of 8, 9, or 10 are vigorous and have breathed within seconds of delivery. In this group, scores of 8 or 9 reflect a lower score for color. The infants with a score of 4 or less are blue and limp and have failed to establish respiration by one minute.” [p1987]

The Apgar score is all about how well a newborn establishes respiration. In contrast to the opinion expressed by White in 1773, Apgar and her colleagues expected that the transition from fetal to neonatal respiration should take place within seconds of delivery.

Apgar et al. (1958) noted that many obstetricians at that time still practiced "slow delivery," waiting for pulsations of the cord to cease, and they suggested that a score could still be assigned, obtaining the heart-rate of the infant by palpating the umbilical cord.

Transfer of placental blood to the alveolar capillaries opens the lungs

100. Jäykkä S. Capillary erection and the structural appearance of fetal and neonatal lungs. *Acta Paediatr.* 1958 Sep;47(5):484-500.

Jäykkä demonstrated that expansion of the lungs results from filling of the capillary bed surrounding the alveoli. Ventilation of non-inflated lungs led to patchy non-uniform opening of the alveoli. Respiration is exchange of carbon dioxide for oxygen via hemoglobin in the lungs or placenta, and of oxygen for carbon dioxide in other organs. Pulmonary respiration cannot begin until blood (laden with carbon dioxide) fills the capillaries that supply the alveoli. An initial exhalation may precede the first breath.

Newborn monkeys subjected to clamping of the umbilical cord and suffocation

101. Ranck JB, Windle WF. Brain damage in the monkey, *Macaca mulatta*, by asphyxia neonatorum. *Exp Neurol.* 1959 Jun;1(2):130-54.

This was the first report of symmetrical bilateral brainstem damage found in monkeys subjected to experimental asphyxia at birth, and that this pattern of damage bore a close resemblance to that seen in kernicterus:

“The human neuropathologic entity most closely resembling the effects of asphyxia neonatorum in the monkey is kernicterus. There are similarities in the distribution and type of nerve cell changes in both conditions. Major differences between the findings in the monkey and those in human infants with kernicterus are absence in the former of the usual history of erythroblastosis fetalis, lack of clinical jaundice, lack of pigment in the lesions, frequent presence of neuroglia cell damage, and presence of marked astrocytic and phagocytic reactions” [p153]

More on the convulsive foal syndrome

102. Mahaffey LW, Rossdale PD (1959) A convulsive syndrome in newborn foals resembling pulmonary syndrome in the newborn infant. *Lancet*. 1959 Jun 13;1(7085):1223-5.

"Variable degrees of traction are usually practised by attendants when the head and forelegs are emerging from the vulva. The amnion is prematurely ruptured by hand, the legs are grasped and a pull is exerted upon them... the umbilical cord is ruptured with such haste that the newborn foal (weighing 100-120 lb.) is deprived of an average of 1020 ml. of blood and often 1500 ml. -- probably about 30% of its potential blood-volume.

Under normal conditions a mare usually rests for period of up to half an hour after parturition, during which the foal also is inactive. The cord remains intact and is not broken until the mare (sometimes the foal) attempts to get to its feet. Meanwhile virtually all the blood in the placenta has passed back into the circulation of the foal, and it is difficult to collect even 50 ml. of blood when the cord ruptures at this stage."

Respiratory distress and continuing pulsation of the umbilical cord stump

103. Desmond MM, Kay JL, Megarity AL (1959) The phases of "transitional distress" occurring in neonates in association with prolonged postnatal umbilical cord pulsations. *Journal of Pediatrics* 55:131-151.

"More recent experience with distressed infants revealed that certain of these infants show disturbances in the closure of umbilical vessels after birth.

...The umbilical arteries normally cease to pulsate within a short period after the infant has been delivered."

... While ligation of the umbilical cord immediately after birth is a tradition in modern obstetrics, the danger of hemorrhage from cords left unligated is not great" [p131]

"Forty-one infants manifested prolonged pulsation of the cord after delivery. The mean duration of cord pulsation was 5 hours, with a range of from 40 minutes to 13 hours after birth." [1, p132]

"Seventy-three per cent of the infants had either fetal distress prior to delivery or difficulty with the onset of respiration on delivery.", [p145]

Apgar's colleague on respiratory distress and delay in onset of respiration

104. James LS. Physiology of respiration in newborn infants and in the respiratory distress syndrome. *Pediatrics*. 1959 Dec;24:1069-101.

James (1959) was co-author with Apgar in 1958 of the paper in which they explained that at the Sloane Hospital (at Columbia University) the umbilical cord was cut within the first minute after birth to preserve the "sterile field," and that all infants with Apgar scores of 8, 9, or 10 had breathed within seconds of delivery. In this paper on respiratory distress a year later, he cites delay in onset of respiration at birth as the primary etiologic factor:

"A review of the obstetrical histories in infants who show a rising respiratory rate has indicated that delayed respiration at birth, even for 2 minutes, seemed to affect markedly both the incidence of abnormal breathing and subsequent." [p1089]

More on respiratory distress syndrome

105. Moss AJ, Duffie ER Jr, Fagan LM. Respiratory distress syndrome in the newborn. Study on the association of cord clamping and the pathogenesis of distress. *JAMA*. 1963 Apr 6;184:48-50.

Reports of respiratory distress syndrome appear to have increased with more and more widespread clamping of the umbilical cord sooner and sooner after birth.

Moss et al. pointed out that pulsations in the cord become progressively weaker and finally cease after the transition from placental to pulmonary respiration is complete. This represents a gradual change-over with only minor alterations in systemic blood flow, but with sudden occlusion of the cord before expansion of the alveolar vascular bed, systemic pressure may cause rupture of capillaries in the lungs, brain, and other organs. They concluded their paper with the following comment:

"The carefree manner in which the newly born infant is 'disconnected' from his 'oxygenator' without any assurance that respirations will ever begin is in sharp contrast to the meticulous care with which the thoracic surgeon separates his patient from the pump-oxygenator." [p50]

1960s textbooks continue to teaching waiting for pulsations of the cord to cease

106. Greenhill JP. *Obstetrics: From the original text of Joseph B. DeLee, MD. Thirteenth Edition.* W.B. Saunders Company, Philadelphia & London, 1965.

"After pulsation in the exposed cord has ceased, using dull scissors, the child is separated from its mother." [p376]

Postnatal placental circulation

107. Stembera ZK, Hodr J, Janda J. Umbilical blood flow in healthy newborn infants during the first minutes after birth. *Am J Obstet Gynecol*. 1965 Feb 15;91:568-74.

In earlier research (published in German and Czech journals) Stembera et al. found that the placenta begins to separate from the wall of the uterus at about 2 minutes after birth, and that the concentration of oxygen in the umbilical arteries begins to decline only 60 to 90 seconds after the first breath. They thus concluded:

"After inclusion of all of our previous data with those in the present communication, it would appear that the first 100 seconds after birth is a period during which the flow and metabolic conditions in the maternal-placental-fetal system continue essentially in a manner similar to that in utero" [p573]

Transfer of blood from placenta to lungs with onset of pulmonary respiration

108. Redmond A, Isana S, Ingall D. Relation of onset of respiration to placental transfusion. *Lancet*. 1965 Feb 6;1:283-5

Redmond et al. measured residual placental blood as an estimate of placental transfusion before and after onset of respiration. In 55 infants, the cord was clamped before onset of respiration, and in 97 after the onset of respiration. The plot of residual blood to onset of respiration from the paper by Redmond et al. shows a dramatic drop in residual blood in cases where the cord was clamped after onset of respiration.

"Our data, obtained from normal uncomplicated pregnancies, clearly demonstrated that a placental transfusion is an inevitable physiological consequence of initial pulmonary expansion, over which obstetricians and paediatricians have little, if any, control."

"The tendency for some obstetricians to deliver the head, aspirate the nose and mouth, and slowly extract the remainder of the baby probably aids the transmission of placental blood to the infant." [p284]

109. Taylor, E. Stewart. *Beck's Obstetrical Practice*, Eight Edition. The Williams & Wilkins company, Baltimore, 1966.

"After delivering the child, the obstetrician suspends it by its feet ... During this time the fluid within the tracheobronchial tree may be expelled by gravity. Most infants take their first extrauterine gasp at this time, and it is well to have the trachea clear."

"If the obstetrician waits until the cord stops pulsating, the child receives a considerable amount of blood (up to 100 ml). This procedure is harmless to the normal infant and may be beneficial. However, the extra blood volume from the placenta may be detrimental in some pathological conditions of the infant. The most notable of these are maternal-fetal blood group incompatibilities, anomalies of the infant cardiovascular system, or severe fetal asphyxia."

"In normal full-term deliveries, the cord is clamped with two hemostats as soon as the cord stops pulsating." [p202]

110. Fitzpatrick E, Eastman NJ, Reeder SR. Maternity Nursing, Eleventh Edition, JB Lippincott Company, Philadelphia, Toronto, 1966.

[1929, 33, 34, 37, 40, Zabriskie's Handbook of Obstetrics, 1st to 6th editions by Louise Zabriskie; 1943, 48, 52, 7th to 9th editions, Zabriskie's Obstetrics for Nurses, Tenth Edition, 1960, by Elise Fitzpatrick & Nicholson J. Eastman]

"...The infant usually cries immediately, and the lungs become expanded; about this time the pulsations in the umbilical cord begin to diminish. The physician usually will defer clamping the cord until this occurs, or for a minute or so if practicable, because of the marked benefit of the additional blood to the infant." [p268]

"Emergency delivery... There is no hurry to cut the cord, so this should be delayed until proper equipment is available. It is a good plan to clamp the cord after pulsations cease (but not imperative at the moment) and to wait for the physician to cut the cord after he arrives." [p288]

Transfer of respiratory function from placenta to lungs

111. Dunn PM. Postnatal placental respiration. Dev Med Child Neurol. 1966 Oct; 8(5): 607-8.

"The transfer of respiratory function from the placenta to the lungs at birth stands out as the most dramatic, complex and important event in our lives. How does this transfer take place? We know that there is often a delay after delivery before breathing commences and that a further interval must pass before pulmonary respiration meets the requirements of the newborn infant [2]. What of the placenta during this time? Does its respiratory function cease at the moment of delivery, or is it maintained until the lungs have assumed their new responsibility?" [p607]

112. Moss AJ, Monset-Couchard M. Placental transfusion: early versus late clamping of the umbilical cord. Pediatrics. 1967 Jul;40(1):109-26.

"Iatrogenic interruption of the placental circulation at birth has, in most cases, become an automatic procedure with little or no regard for the physiologic alterations evoked or for their subsequent effect upon the fetus." [p109]

A safe period of anoxia?

113. James LS. Resuscitation of the newborn, in DE Reid and TC Barton, eds, Controversy in Obstetrics and Gynecology. Philadelphia, London, Toronto: WB Saunders Company, 1969.

Apgar's colleague discussed problems of C-section as result of loss of uterine contractions, not of cutting the umbilical cord prematurely:

"In infants delivered by cesarean section, hemoglobin, hematocrit value, and blood pressure have frequently been found to be lower than in infants delivered per vaginam ... due to a loss of blood into the placenta, since the uterus is not contracting."

James' interpretation of the effects of asphyxia on newborn monkeys suggests he regarded a short episode of oxygen insufficiency as safe, not that he and Apgar should revise their practice of clamping the cord within one minute after birth:

"Asphyxiated newborn monkeys resuscitated before the last gasp show little or no cerebral damage. On the other hand prolongation of asphyxia for as short a period as four minutes after the last gasp is accompanied by widespread tissue damage and abnormal behavior in the surviving animals. Thus for the newborn monkey the 'safe' period of anoxia is short if functional integrity is to be maintained." [pp220-221]

Disruption of brain maturation in monkeys asphyxiated at birth

114. Faro MD, Windle WF. Transneuronal degeneration in brains of monkeys asphyxiated at birth. *Exp Neurol.* 1969 May;24(1):38-53.

Abstract: "Brain damage occurring from 10 months to 8 years 9 months after neonatal asphyxiation for 11.5-17 min was assessed histologically in 12 rhesus monkeys. Comparison was made with brains of ten monkeys asphyxiated for brief periods or living shorter times and with those of five nonasphyxiated controls. Very slight damage occurred after 6-7 min of asphyxia; major destruction of relay nuclei in afferent input systems and parts of the basal ganglia, after 11.5-17 min. In the course of time, beginning about 10 months after birth, secondary transneuronal degeneration became evident. This was most clearly seen in the parts of the cerebral cortex which had received projections from the thalamic nuclei destroyed during the asphyxia; also in other thalamic nuclei and the brain-stem reticular formation. Gradual improvement in physical status and in behavioral responses to environment occurred while brain structure deteriorated."

115. Windle WF. Brain damage by asphyxia at birth. *Sci Am.* 1969 Oct;221(4):76-84.

"...in any delivery it is important to keep the umbilical cord intact until the placenta has been delivered. To clamp the cord immediately is equivalent to subjecting the infant to a massive hemorrhage, because almost a fourth of the fetal blood is in the placental circuit at birth." [p78]

“The monkey experiments described in this article have taught us that birth asphyxia lasting long enough to make resuscitation necessary always damages the brain.” [p84]

Brief anoxia at birth versus prolonged partial hypoxia

116. Myers RE. Two patterns of perinatal brain damage and their conditions of occurrence. *Am J Obstet Gynecol.* 1972 Jan 15;112(2):246-76.

In more experiments with monkeys, Myers confirmed that the symmetric bilateral pattern of brainstem damage is caused by eight or more minutes of total oxygen cutoff at birth, and that prolonged partial hypoxia in utero results in the pattern of cortical damage associated with cerebral palsy.

1970s bilirubin and other uncertainties

117. Saigal S, O'Neill A, Surainder Y, Chua LB, Usher R. Placental transfusion and hyperbilirubinemia in the premature. *Pediatrics.* 1972 Mar;49(3):406-19.

Is it safe to allow a placental transfusion? By the 1970s the practice of clamping the cord was so widespread, at least in obstetric practice associated with academic institutions, that whether a placental transfusion should be allowed became a major topic for research. Thus the opening comment of this highly influential report states:

"In full-term infants placental transfusion increases the blood volume of the newborn by 40% to 60% within 5 minutes of birth. Most of the excess blood volume is eliminated within 4 hours by an extravasation of plasma from the circulation. For the remainder of the neonatal period, such infants retain a 50% larger red cell volume dispersed through a slightly enlarged blood volume, with higher hematocrit values than are found in infants whose umbilical cords are clamped immediately at birth." [p406]

"If delayed cord clamping is adopted as a means to reduce the incidence of respiratory distress syndrome in premature births, there will be accompanying augmentation of hyperbilirubinemia to deal with." [p418]

This paper, with its single focus on bilirubin danger, has been one of the most influential in adopting immediate clamping of the umbilical cord at birth as a standard protocol.

Neuropathology of foals born with human assistance found similar to that in monkeys

118. Palmer AC, Rossdale PD. (1975) Neuropathology of the convulsive foal syndrome. *J Reprod Fertil Suppl.* 1975 Oct;(23):691-4.
119. Palmer AC, Rossdale PD. (1976) Neuropathological changes associated with the neonatal maladjustment syndrome in the thoroughbred foal. *Res Vet Sci.* 1976 May;20(3):267-75.

Palmer and Rossdale found brain damage in thoroughbred foals delivered with human assistance similar to that found in monkeys subjected to asphyxia at birth.

Continuing fear of elevated bilirubin

120. Beischer, Norman A & MacKay Eric V. *Obstetrics and The Newborn: For midwives and medical students*. W.B. Saunders: Philadelphia, 1976.

"The optimal time for clamping (or tying) the cord is not known for certain. Late clamping of the cord results in an additional volume of blood reaching the infant. This is harmful in premature and erythroblastotic infants.

In the asphyxiated infant, early clamping allows rapid transfer of the child for resuscitation purposes. In other patients, the cord is clamped when pulsations cease." [p395]

121. Saigal S, Usher RH. Symptomatic neonatal plethora. *Biol Neonate*. 1977;32(1-2):62-72

In this paper Saigal and Usher (1977) described "symptomatic neonatal plethora" in 8 premature and 3 full-term infants with the suggestion that these conditions were caused by "large placental transfusions associated with delayed clamping of the umbilical cord" [p62]. Saigal and Usher stated implications of their findings as follows.

"After many years of controversy, the question of when to clamp the umbilical cord seems to be resolving towards a middle course. Excessive delay (more than 2 min) in cord clamping produces hyperbilirubinemia and sometimes symptomatic hypervolemia or polycythemia. Immediate cord clamping in premature infants tends to increase mortality from respiratory distress syndrome. It seems advisable, therefore, to delay cord clamping for 1 to 1 1/2 min in premature infants, with less delay in full-term infants." [2, p70]

Clamping the cord soon after delivery had become the norm. There seemed to be no memory of the traditional teaching of textbooks, or research from less than 20 years earlier [3]. Treatment of mothers in premature labor with betamethasone, and neonatal use of surfactant were being used to prevent respiratory distress syndrome and hyaline membrane disease of the lungs.

The association of lung pathology with clamping of the umbilical cord had become irrelevant, and placental transfusion was now regarded as a potential hazard.

1980s textbook teachings, from tradition to confusion and change

122. Bodyazhina V. *Textbook of Obstetrics: Translated from the Russian by Alexander Rosinkin (revised from the 1980 edition)*. Mir Publishers, Moscow, 1983.

"The umbilical cord should be tied up after its vessels stop pulsating, which occurs in 2-3 min following the delivery of the infant. In the course of a few minutes that the umbilical cord pulsates, from 50 to 100 ml of the blood is delivered into the vascular system of the foetus from the placenta. As soon as the pulsation discontinues, the cord should be cut off and tied up in aseptic conditions." [p156]

123. Beischer NA, MacKay EV (1986) *Obstetrics and the Newborn: An illustrated textbook*, Second Edition. WB Saunders Company, Philadelphia, 1986.

"The optimum time of clamping is 30-60 seconds after birth: This will provide some 80 ml of extra blood to the baby. Excess blood volume in the baby can be a disadvantage, producing polycythemia and hyperviscosity, with such attendant problems as respiratory distress, heart failure, jaundice, convulsions and apathy." [p381]

"Apgar scores are recorded at 1 minute and again at 5 minutes, timing the observations accurately... Also the time to first breath and time to the establishment of regular respirations are recorded.

... Permanent cord clamps or ligatures (Figure 26.27) or special bands are applied to the umbilical cord as soon as possible after birth..." [p470]

"The optimal time for clamping (or tying) the cord is not known for certain. Late clamping of the cord results in an additional volume of blood reaching the infant. This may result in hyperviscosity, jaundice and cardiorespiratory, neurological and renal problems. The extra blood specifically aggravates jaundice in premature infants and in those with erythroblastosis, so early clamping of the cord is advised in such infants." [p546]

"Q: What is the significance of continued pulsation of the arteries in the umbilical cord at birth?

A: It means that respiration has not commenced. The physiological stimulus causing closure of umbilical arteries (and ductus arteriosus) is an increase in oxygen saturation of the blood which occurs when the lungs expand with air." [p710]

"Routine practices concerning the time for clamping the umbilical cord vary. If the child's condition is satisfactory cord clamping and severing can be delayed until pulsation has stopped and the infant is position at or below the level of the mother. The additional blood transfused from the placenta can be as much as 100 ml. The benefits of this are not fully evaluated but the additional volume may be harmful in preterm infants. Early clamping facilitates prompt resuscitation, if required, and transfer to the mother's arms..." [pp734-5]

124. Kraybill, EN. Needs of the term infant, In GB Avery, MA Fletcher, & MG MacDonald, eds. Neonatology. Pathophysiology and Management of the Newborn, Third Edition. JB Lippincott, Philadelphia, 1987.

"... with present information it seems reasonable to avoid the extremes of immediate and of very late clamping. The first 30 to 60 seconds after delivery are well spent in suctioning the airway ... The normal newborn invariably cries during this interval ..." [p258]

Continuing respect for nature's plan

125. Dunn PM. Stress failure of pulmonary capillaries at birth. Lancet. 1993 Jan 9;341(8837):120.

"My own interest stems from studies (1960-73) on fetal adaption to extrauterine life. These results showed that preterm infants delivered by caesarean section were much less likely to develop and die from RDS [respiratory distress syndrome] if pulmonary respiration was established while the umbilical circulation was still intact and if positive-pressure ventilation, when required, was gentle with the aim of evacuating lung fluid through the lymphatic system, rather than of inflating the lungs. I argued that sudden occlusion of the vigorously pulsating cord of an apnoeic infant would, by cutting off the low-resistance placental circulation, lead to a sharp transitory rise in systemic blood pressure. This, in turn would lead to transitory heart failure and a raised venous pressure, especially if acute placental transfusion hypervolaemia was also present. At the same time the rise in systemic blood pressure would be transmitted through the patent ductus arteriosus to the pulmonary arteries, just as lung expansion was leading to a sudden fall in pulmonary vascular resistance."

126. Mercer JS, Skovgaard RL. Neonatal transitional physiology: a new paradigm. J Perinat Neonatal Nurs. 2002 Mar;15(4):56-75.

Mercer and Skovgaard brought attention to Jäykkä's research in their analysis of blood volume redistribution required by all body organs following birth.

"The hypothesis proposed is that a successful neonatal transition is dependent upon a newborn having an adequate blood volume to recruit the lung for respiratory function through capillary erection and an adequate *red cell* volume to provide enough oxygen delivery to stimulate and maintain respiration." [p59]

Respiratory depression at birth

127. Milsom I, Ladfors L, Thiringer K, Niklasson A, Odeback A, Thornberg E. Influence of maternal, obstetric and fetal risk factors on the prevalence of birth asphyxia at term in a Swedish urban population. Acta Obstet Gynecol Scand. 2002 Oct;81(10):909-17.

“During the 7-year period 1985–91, the incidences of low Apgar score (< 7 at 5 min), pure birth asphyxia and birth asphyxia with HIE in this population were 6.9, 5.4 and 1.8 per 1000 live born infants, respectively” [p911]

128. Baskett TF, Allen VM, O'Connell CM, Allen AC. Predictors of respiratory depression at birth in the term infant. *BJOG*. 2006 Jul;113(7):769-74.

“Overall, the rate of respiratory depression at birth was low (6.2/1000) and the rate of the serious manifestation of seizures was less than 1 in 1000.” [p772]

Autism prevalence

129. Chakrabarti S, Fombonne E. Pervasive developmental disorders in preschool children: confirmation of high prevalence. *Am J Psychiatry*. 2005 Jun;162(6):1133-41.

“Sixty-four children (85.9% boys) were diagnosed with pervasive developmental disorders. The prevalence was 58.7 per 10,000” [p1133]

130. Nicholas JS, Charles JM, Carpenter LA, King LB, Jenner W, Spratt EG. Prevalence and characteristics of children with autism-spectrum disorders. *Ann Epidemiol*. 2007 Sep; 17(9):747-8. 2008 Feb;18(2):130-6.

“Cases from the first two study years (2000 and 2002) have been combined for this analysis. RESULTS: A total of 296 children met criteria for ASD, yielding a prevalence of 6.2 per 1000.” [2007, p748]

Cases from South Carolina... surveillance of 47,726 children who are 8 years of age... 295 children met criteria for ASD... “CONCLUSIONS: Results indicate that ASDs affect 1 in 162 children 8 years of age in South Carolina.” [2008, abstract]

131. Center for Disease Control updates <http://www.cdc.gov/ncbddd/autism/> (accessed 6/28/08)

132. Park A. How safe are vaccines? *Time Magazine*. 2008 Jun 2;171(22):36-41.

“Autism 1 in 150: The prevalence of autism among 8-year-olds in the U.S. Autism rates have not declined, even though thimerosal, which some believe contributes to the disease, was removed from vaccines in 2001.” [p38]

Perinatal complications in autism

133. Lobascher ME, Kingerlee PE, Gubbay SS. Childhood autism: an investigation of aetiological factors in twenty-five cases. *Br J Psychiatry*. 1970 Nov;117(540):525-9.

"There were more complications of labour in the experimental group than the controls (p=0.001) ...Abnormal conditions of the child noted at delivery occurred significantly more frequently in the experimental group, e.g. difficulty with

resuscitation, cord around neck, fractured skull, cyanosis, head moulding, bruising, jaundice ($p < 0.0004$)."

134. Levy S, Zoltak B, Saelens T. A comparison of obstetrical records of autistic and nonautistic referrals for psychoeducational evaluations. *J Autism Dev Disord.* 1988 Dec;18(4):573-81.

"Abnormal presentation at birth is the only factor that occurred more frequently for the autistic sample..."

135. Steffenburg S, Gillberg C, Hellgren L, Andersson L, Gillberg IC, Jakobsson G, Bohman M. A twin study of autism in Denmark, Finland, Iceland, Norway and Sweden. *J Child Psychol Psychiatry.* 1989 May;30(3):405-16.

"In most of the pairs discordant for autism, the autistic twin had more perinatal stress."

136. Lord C, Mulloy C, Wendelboe M, Schopler E. Pre- and perinatal factors in high-functioning females and males with autism. *J Autism Dev Disord.* 1991 Jun;21(2):197-209.

"These data provide slight support for the contribution of nonspecific pre- and perinatal factors to other etiological bases of autism."

137. Ghaziuddin M, Shakal J, Tsai L. Obstetric factors in Asperger syndrome: comparison with high-functioning autism. *J Intellect Disabil Res.* 1995 Dec;39 (Pt 6):538-43.

"Males with AS showed a trend toward lower Apgar scores at one minute ..."

138. Bolton PF, Murphy M, Macdonald H, Whitlock B, Pickles A, Rutter M. Obstetric complications in autism: consequences or causes of the condition? *J Am Acad Child Adolesc Psychiatry.* 1997 Feb;36(2):272-81

"...[obstetric] optimality score (OS), were compared in two groups: 78 families containing an autistic proband (ICD-10 criteria) and 27 families containing a down syndrome (DS) proband... RESULTS: Autistic and DS probands had a significantly elevated OS compared with unaffected siblings, regardless of birth order position. The elevation was mainly due to an increase in mild as opposed to severe obstetric adversities."

139. Matsuishi T, Yamashita Y, Ohtani Y, Ornitz E, Kuriya N, Murakami Y, Fukuda S, Hashimoto T, Yamashita F. Brief report: incidence of and risk factors for autistic disorder in neonatal intensive care unit survivors. *J Autism Dev Disord.* 1999 Apr;29(2):161-6.

"**AD was identified in 18 of the 5,271 children** and the incidence was 34 per 10,000 (0.34%). This value was more than twice the highest prevalence value previously reported in Japan. **Children with AD had a significantly higher history of the meconium aspiration syndrome** ($p = .0010$) than the controls. Autistic patients had

different risk factors than CP." **Note: CP (cerebral palsy) occurred in 57 of the 5,271 children."**

140. Bodier C, Lenoir P, Malvy J, Barthélemy C, Wiss M, Sauvage D. (2001) Autisme et pathologies associées. Étude clinique de 295 cas de troubles envahissants du développement [Autism and associated pathologies. Clinical study of 295 cases involving development disorders]. Presse Médicale. 2001 Sep 1;30(24 Pt 1):1199-203.

"Among the children with a serious medical condition, 34.4% also had ante- or perinatal antecedents. Among the 33% without any medical factor, 77% also had ante- or perinatal antecedents."

141. Juul-Dam N, Townsend J, Courchesne E. Prenatal, perinatal, and neonatal factors in autism, pervasive developmental disorder-not otherwise specified, and the general population. Pediatrics. 2001 Apr;107(4):E63.

"... specific complications that carried the highest risk of autism and PDD-NOS represented various forms of pathologic processes with no presently apparent unifying feature."

142. Greenberg DA, Hodge SE, Sowinski J, Nicoll D. Excess of Twins among Affected Sibling Pairs with Autism: Implications for the Etiology of Autism. Am J Hum Genet. 2001 Nov;69(5):1062-7.

"In a sample of families selected because each had exactly two affected sibs, we observed a remarkably high proportion of affected twin pairs, both MZ and DZ..."

143. Wilkerson DS, Volpe AG, Dean RS, Titus JB. Perinatal complications as predictors of infantile autism. Int J Neurosci. 2002 Sep;112(9):1085-98.

"... 5 items were found to significantly predict group membership (prescriptions taken during pregnancy, length of labor, viral infection, abnormal presentation at delivery, and low birth weight)."

144. Hultman CM, Sparen P, Cnattingius S. Perinatal risk factors for infantile autism. Epidemiology. 2002 Jul;13(4):417-23.

"The **risk of autism** was associated with daily smoking in early pregnancy (OR = 1.4; CI = 1.1-1.8), maternal birth outside Europe and North America (OR = 3.0; CI = 1.7-5.2), cesarean delivery (OR = 1.6; CI = 1.1-2.3), being small for gestational age (SGA; OR = 2.1; CI = 1.1-3.9), a **5-minute Apgar score below 7** (OR = 3.2, CI = 1.2-8.2), and congenital malformations (OR = 1.8, CI = 1.1-3.1)." **Note: The OR (odds ratio) was greatest for 5-min Apgar score below 7."**

145. Zwaigenbaum L, Szatmari P, Jones MB, Bryson SE, MacLean JE, Mahoney WJ, Bartolucci G, Tuff L. Pregnancy and birth complications in autism and liability to the broader autism phenotype. J Am Acad Child Adolesc Psychiatry 2002 May;41(5):572-9.

"Children with autism spectrum disorders have lower optimality (higher rates of complications) than unaffected siblings..."

146. Glasson EJ, Bower C, Petterson B, de Klerk N, Chaney G, Hallmayer JF. Perinatal factors and the development of autism: a population study. *Arch Gen Psychiatry*. 2004 Jun;61(6):618-27.
- "Cases were more likely to have experienced fetal distress during labor (OR, 1.64; 95% CI, 1.15-2.34). Apgar scores calculated at 1 minute showed that significantly more cases achieved a score of 6 or less (54 [19.5%] of 277 cases with data recorded since 1991..." "[12.9%] of 512 control subjects with data recorded since 1991)(OR, 1.6; 95% CI, 1.1-2.4), and cases were more likely to have taken more than 1 minute before the onset of spontaneous respiration (OR, 1.4; 95% CI, 1.0-1.9)."
147. Cederlund M, Gillberg C. One hundred males with Asperger syndrome: a clinical study of background and associated factors. *Dev Med Child Neurol*. 2004 Oct;46(10):652-60.
- For 58 of 99 children, some kind of abnormality was noted in their neonatal record. ... Twenty-two had had hyperbilirubinemia (plasma bilirubin more than 200 μ mol/l), ... Hyperbilirubinemia occurs in about 10% of newborn infants... Forty-five of 92 children (49%) for whom fairly detailed data about early language development were available, clearly did not have normal language development at 2 years of age. It cannot be concluded that the remainder had normal language development.
148. Larsson HJ, Eaton WW, Madsen KM, Vestergaard M, Olesen AV, Agerbo E, Schendel D, Thorsen P, Mortensen PB. Risk factors for autism: perinatal factors, parental psychiatric history, and socioeconomic status. *Am J Epidemiol*. 2005 May 15;161(10):916-25; discussion 926-8.
- "In the unadjusted analyses, breech presentation, lowApgar score (less than or equal 7) at 5 minutes, low birth weight (less than or equal 2,500 g), gestational age at birth of less than 35 weeks, and being small for gestational age were associated with a statistically significantly increased risk of autism..."
149. Newschaffer CJ, Cole SR. Invited commentary: risk factors for autism--perinatal factors, parental psychiatric history, and socioeconomic status. *Am J Epidemiol*. 2005 May;161:926-8.
150. McInnes LA, Gonzalez PJ, Manghi ER, Esquivel M, Monge S, Delgado MF, Fournier E, Bondy P, Castelle K. A genetic study of autism in Costa Rica: multiple variables affecting IQ scores observed in a preliminary sample of autistic cases. *BMC Psychiatry*. 2005 Mar 21;5(1):15.
151. Gillberg C, Cederlund M. Asperger syndrome: familial and pre- and perinatal factors. *J Autism Dev Disord*. 2005 Apr;35(2):159-66.

"Five children had had an Apgar score of 6 or under at 1, 5 , or 10 minutes, and 3 of these had scores of 1 or 2 (i.e., they had severe postnatal asphyxia). ... Of the 100 individuals, 58 had one or more remarks in their birth- or perinatal records about a serious problem in the peri-/neonatal period."

152. Badawi N, Novak I, McIntyre S, Edwards K, Raye S, deLacy M, Bevis E, Flett P, van Essen P, Scott H, Tungaraza K, Sealy M, McCann V, Reddihough D, Reid S, Lanigan A, Blair E, de Groot J, Watson L. Autism following a history of newborn encephalopathy: more than a coincidence? *Dev Med Child Neurol*. 2006 Feb;48(2):85-9.

"... in a population-based study of moderate and severe term newborn encephalopathy (NE) in Western Australia ...infants with NE were 5.9 (95% CI 2.0–16.9) times more likely to be diagnosed with an ASD than controls... this was not an expected association at the outset of the study"

153. Maimburg RD, Vaeth M. Perinatal risk factors and infantile autism. *Acta Psychiatr Scand*. 2006 Oct;114(4):257-64.

" We also found strong associations between children with infantile autism and mothers with foreign citizenship, children with congenital malformations and children who needed treatment at Neonatal Intensive Care Unit (NICU) after birth. When the caesarean sections were categorized into scheduled and unscheduled procedures, we found only scheduled caesarean sections to be associated with infantile autism."

154. Kolevzon A, Gross R, Reichenberg A. Prenatal and perinatal risk factors for autism: a review and integration of findings. *Arch Pediatr Adolesc Med*. 2007 Apr;161(4):326-33.

"According to our review, 3 parental characteristics and 2 obstetric conditions emerge as potential risk factors for autism: namely, paternal age, maternal age, maternal immigration, growth restriction, and newborn hypoxia. In analyses that adjusted for confounding variables, these factors usually remained statistically significant."

155. van Handel M, Swaab H, de Vries LS, Jongmans MJ. Long-term cognitive and behavioral consequences of neonatal encephalopathy following perinatal asphyxia: a review. *Eur J Pediatr*. 2007 Apr 11; [Epub ahead of print].

"Most outcome studies have focused on neurological functioning and severe deficits in young children (<4 years). In general, very few children with mild encephalopathy show neurological impairments or have developed severe mental or motor retardation at preschool age. ... Only a few studies looked at the behavioral consequences of NE. Those studies found elevated rates of hyperactivity and autism in children with moderate NE."

Symmetric bilateral damage of brainstem nuclei caused by anoxia

156. Gilles FH. Selective symmetrical neuronal necrosis of certain brain stem tegmental nuclei in temporary cardiac standstill [Abstract of presentation at the American Association of Neuropathologists: 38th Annual Meeting. Atlantic City. New Jersey]. *J Neuropathol Exp Neurol* 1963 Apr; 22(2):318.

Gilles reported pathology similar to that observed by Ranck & Windle in an 18-month-old infant who died a few weeks following resuscitation from drowning. He also suggested that the brainstem pattern of damage with prominent involvement of the inferior colliculi (in the midbrain auditory pathway) might lead to developmental language delay.
157. Gilles FH. Hypotensive brain stem necrosis. Selective symmetrical necrosis of tegmental neuronal aggregates following cardiac arrest. *Arch Pathol.* 1969 Jul;88(1):32-41.
158. Norman MG (1972) Antenatal neuronal loss and gliosis of the reticular formation, thalamus, and hypothalamus. A report of three cases. *Neurology.* 1972 Sep;22(9):910-6.
159. Griffiths AD, Laurence KM. The effect of hypoxia and hypoglycaemia on the brain of the newborn human infant. *Dev Med Child Neurol.* 1974 Jun;16(3):308-319.
160. Grunnet ML, Curless RG, Bray PF, Jung AL. Brain changes in newborns from an intensive care unit. *Dev Med Child Neurol.* 1974 Jun;16(3):320-8.
161. Schneider H, Ballowitz L, Schachinger H, Hanefield F, Droeszus J-U. Anoxic encephalopathy with predominant involvement of basal ganglia, brain stem and spinal cord in the perinatal period. Report on seven newborns. *Acta Neuropathol.* 1975 Oct 1;32(4):287-98.
162. Smith JF, Rodeck C. Multiple cystic and focal encephalomalacia in infancy and childhood with brain stem damage. *J Neurol Sci.* 1975 Jul;25(3):377-88.
163. Leech RW, Alvord EC Jr, Anoxic-ischemic encephalopathy in the human neonatal period, the significance of brain stem involvement. *Arch Neurol.* 1977 Feb;34(2):109-13.
164. Roland EH, Hill A, Norman MG, Flodmark O, MacNab AJ. Selective brainstem injury in an asphyxiated newborn. *Ann Neurol.* 1988 Jan;23(1):89-92.
165. Natsume J, Watanabe K, Kuno K, Hayakawa F, Hashizume Y. Clinical, neurophysiologic, and neuropathological features of an infant with brain damage of total asphyxia type (Myers). *Pediatr Neurol.* 1995 Jul;13(1):61-4.

Symmetric bilateral brainstem damage caused by toxic substances

166. Bini L and Bollea G (1947). Fatal poisoning by lead-benzine (a clinico-pathologic study). *Journal of Neuropathology and Experimental Neurology* 1947; 6:271-285.

167. Franken L Étude anatomique d'un cas d'intoxication par le bromure de méthyle. [Anatomical study of a case of methylbromide poisoning. *Acta Neurol Psychiatr Belg.* 1959 Mar;59(3):375-83.
168. von Rogulja P, Kovac W, Schmid H. Metronidazol-Encephalopathie der Ratte. *Acta Neuropathol.* 1973 Jun 26;25(1):36-45.
169. Goulon M, Nouailhat R, Escourolle R, Zarranz-Imirizaldu JJ, Grosbuis S, Levy-Alcover MA (1975). Intoxication par le bromure de methyl: Trois observations, dont une mortelle. Etude neuro-pathologique d'un cas de stupeur avec myoclonies, suivi pendent cinq ans. *Revue Neurologique (Paris)* 131:445-468.
170. Dunn PM, Stewart-Brown S, Peel R. Metronidazole and the fetal alcohol syndrome. *Lancet.* 1979 Jul 21;2(8134):144.
171. Bertoni JM, Sprengle PM. Lead acutely reduces glucose utilization in the rat brain especially in higher auditory centers. *Neurotoxicology.* 1988 Summer;9(2):235-42.
172. Oyanagi K, Ohama E, Ikuta F. The auditory system in methyl mercurial intoxication: a neuropathological investigation on 14 autopsy cases in Niigata, Japan. *Acta Neuropathol.* 1989;77(6):561-8.
173. Squier MV, Thompson J, Rajgopalan B. Case report: neuropathology of methyl bromide intoxication. *Neuropathol Appl Neurobiol.* 1992 Dec;18(6):579-84.
174. Cavanagh JB. Methyl bromide intoxication and acute energy deprivation syndromes. *Neuropathol Appl Neurobiol.* 1992 Dec;18(6):575-8.
175. Cavanagh JB. Selective vulnerability in acute energy deprivation syndromes. *Neuropathol Appl Neurobiol.* 1993 Dec;19(6):461-70.
176. Cavanagh JB, Nolan CC. The neurotoxicity of alpha-chlorohydrin in rats and mice: II. Lesion topography and factors in selective vulnerability in acute energy deprivation syndromes. *Neuropathol Appl Neurobiol.* 1993 Dec;19(6):471-9.
177. Husain K, Whitworth C, Hazelrigg S, Rybak L. Carboplatin-induced oxidative injury in rat inferior colliculus. *Int J Toxicol.* 2003 Sep-Oct;22(5):335-42.
178. Kenet T, Froemke RC, Schreiner CE, Pessah IN, Merzenich MM. Perinatal exposure to a noncoplanar polychlorinated biphenyl alters tonotopy, receptive fields, and plasticity in rat primary auditory cortex. *Proc Natl Acad Sci U S A.* 2007 May 1;104(18):7646-51.

Disrupted brain maturation in autism

179. Bauman ML, Kemper TL. Neuroanatomic observations of the brain in autism: a review and future directions. *Int J Dev Neurosci.* 2005 Apr-May;23(2-3):183-7.
180. Müller RA. The study of autism as a distributed disorder. *Ment Retard Dev Disabil Res Rev.* 2007;13(1):85-95. Review. Erratum in: *Ment Retard Dev Disabil Res Rev.* 2007;13(2):195.

181. Amaral DG, Schumann CM, Nordahl CW. Neuroanatomy of autism. *Trends Neurosci.* 2008 Mar;31(3):137-45.

What causes kernicterus (jaundice of subcortical brain nuclei)?

182. Zimmerman HM, Yannet H. Kernicterus: jaundice of the nuclear masses of the brain. *American Journal of Diseases of Children* 1933 Apr; 45:740-759.

Before discovery of Rh factor sensitivity, Zimmerman and Yannet in 1933 summarized a large number of case reports of kernicterus. They concluded that kernicterus was caused by bilirubin staining of subcortical nuclei already injured by sepsis or oxygen deprivation. They further commented, "This differs in no way from the well known fact that any intravital dye will localize in zones of injury and will leave unstained tissues which are not damaged," [p757].

Fear of elevated bilirubin levels became a prime reason 40 years later for advocating immediate clamping of the umbilical cord at birth – to minimize placental transfusion.

Effects of asphyxia on the brain, and asphyxia plus circulating toxins

183. Lucey JF, Hibbard E, Behrman RE, Esquivel FO, Windle WF. Kernicterus in asphyxiated newborn monkeys. *Exp Neurol* 1964 Jan; 9(1):43-58.

Lucey et al induced hyperbilirubinemia in fourteen newborn monkeys by injecting a solution of bilirubin into the bloodstream every six hours. Bilirubin levels of 20 to 35 mg were maintained for up to 96 hours.

Then, "Six healthy full-term monkeys were asphyxiated at birth. A rubber bag filled with saline solution was placed over the fetal head as it was delivered from the uterus before the first breath. The umbilical cord was then clamped and asphyxiation carried out for 10 or 12 minutes" [p45]. Hyperbilirubinemia was then induced in the asphyxiated monkeys as in the fourteen control animals.

Lucey et al described the monkeys made hyperbilirubinemic as showing marked yellow coloration of skin and mucous membranes. Those not asphyxiated became slightly lethargic but none developed signs of neurological impairment. Monkeys subjected to asphyxia before induction of hyperbilirubinemia developed tremors, seizures, and prolonged periods of opisthotonus (a postural state with arched back and neck).

"Hyperbilirubinemia alone did not result in selective staining of nuclei in the brain, such as is associated with human kernicterus ... the brains had a diffuse, faint to moderate, yellow color, but no extravascular bilirubin was seen" [p50].

Bilirubin is not directly toxic to the brain. Asphyxia causes break-down of the blood-brain barrier, which then allows bilirubin to get into neural cells. As Zimmerman and Yannet noted in 1933, "any intravital dye will localize in zones of injury and will leave unstained tissues which are not damaged." [39, p757]

184. Lou HC, Tweed WA, Johnson G, Jones M, Lassen NA. Breakdown of blood/brain barrier in kernicterus. *Lancet*. 1977 May 14;1(8020):1062-3.

Lou et al. (1977) addressed what appeared to be the primary concern over "delayed" cord clamping allowing placental transfusion [1]. Citing the paper by Lucey et al. (1964) [2] they stated:

"Asphyxiated infants are especially susceptible to kernicterus, even if their plasma-bilirubin levels are low.' Furthermore, it is very difficult to produce clinical and pathological signs of kernicterus by injection of bilirubin intravenously in normal infant monkeys, while kernicterus was readily produced in previously asphyxiated monkeys." [1, p1062]

Mossakowski et al.[The early histochemical and ultrastructural changes in perinatal asphyxia. *J Neuropathol Exp Neurol*. 1968 Jul;27(3):500-516] used Evans blue dye to investigate the blood-brain barrier in newborn monkeys subjected to asphyxia by clamping the umbilical cord and obstructing the airway [69]. Lou et al. also used Evans blue dye in fetal lambs subjected to oxygen insufficiency for 1-2 hours:

"The fetuses were asphyxiated by partially inflating a cuff around the umbilical cord. Asphyxia developed over a period of 1-2 h (pH about 6.90)." [1, p1062]

The initial response of the fetal lambs was a slowing of heart rate and increased blood pressure during the first half- to one-hour period of umbilical cord blood flow restriction. After that the blood pressure declined and remained low. Twinning is frequent in lambs, and Lou et al. used the twin as a control for the fate of Evans blue dye, and reported:

"We have found, in experimental asphyxia lasting 1-2 h, a striking discoloration throughout cortex and basal ganglia after intravenous injection of 3 ml/kg of a 2% solution of Evans blue in eight non-exteriorised fetal lambs, in contrast to the uncoloured brain tissue in non-asphyxiated twins acting as controls." [1, p1062]

In conclusion they commented: "We suggest that the breakdown of the fetal blood/brain barrier to albumin is due to a combination of the initial moderate hypertension and severe vasodilation during asphyxia.⁷ The permeability of the blood/brain barrier to albumin in asphyxiated babies would facilitate the transport of bilirubin from plasma to neurones and thus

explain the increased
susceptibility to kernicterus." [1, p1063]

185. Lou HC, Lassen NA, Tweed WA, Johnson G, Jones M, Palahniuk RJ. Pressure passive cerebral blood flow and breakdown of the blood-brain barrier in experimental fetal asphyxia. *Acta Paediatr Scand*. 1979 Jan;68(1):57-63.
