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PAPER

PATHOLOGY/BIOLOGY

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Patterns of Breaks in Umbilical Cords by Different Mechanisms*

ABSTRACT: Investigations of perinatal deaths often result in discrepancies between autopsy findings and witness accounts. The mechanism by which the umbilical cord is severed after delivery is a common quandary. Confirming or refuting the mother's stated method frequently has significant investigative importance; however, a surprising paucity of data currently exists to allow an objective opinion about the likely mechanism. Ninety-nine placentas with umbilical cords were examined. By random selection, each cord was severed by one of the following tools or mechanisms: knives, scissors, traction, or crush. Each break was examined and photographed, and a tissue section from the broken end examined microscopically. Differentiation of mechanism was best done grossly based on specific pattern recognition. Umbilical cords severed by blunt force have distinctly different morphology from those severed by sharp force. Even similar-appearing sharp force transections frequently have mechanism-specific distinctive patterns of injury.

KEYWORDS: forensic science, forensic pathology, umbilical cord, neonaticide, injury, trauma, perinatal mortality, patterns, fetus

Investigations of perinatal deaths are simplified when postmortem examination, law enforcement reports, and witness accounts suggest a similar sequence of events. During the investigation of a case involving a young woman who delivered a child at home following a concealed pregnancy, many discrepancies arose between the mother's reports and law enforcement's findings. The mother brought the deceased fetus to an obstetrician-gynecologist's office wrapped in a bath towel. After delivering the placenta, the clinician sent the placenta and fetus to the medical examiner to determine whether this baby had been born alive or stillborn. The external examination of the fetus showed a short segment of umbilical cord attached to its anterior abdomen. The distal end of the cord had a smooth, flat surface that appeared consistent with having been cut by a fairly sharp object. According to the mother's testimony, she had delivered the baby into the toilet and subsequently blacked out, and the cord tore as a result of being pulled over the side of the toilet seat. A thorough search through the forensic literature showed that there was very little available data that allowed forensic pathologists to produce an objective determination of the tool or mechanism used to sever an umbilical cord.

The purpose of this study is to provide medical examiners with an objective, reproducible finding to apply to these already-difficult cases with often significant legal consequences.

Materials and Methods

Approval was obtained from the Internal Review Board at the Graduate School of Medicine and the University of Tennessee Medical Center, Knoxville, Tennessee, to conduct a patient consent exemption study involving the collection of human placentas. To simulate a real-life scenario where an umbilical cord is separated by some mechanism, the representative placentas had to be as varied as the general population. To establish a foundation of data on the topic, all placentas that did not require pathologic examination per the obstetrician were included in this study until a total of 99 placentas had been collected. Given the number of specimens, an appropriate cross-section of the population is likely represented. All specimens were collected under HIPAA guidelines and in accordance with the ethical standards of the University of Tennessee Medical Center–Knoxville's Committee on Human Experimentation. Each placenta was labeled with the gestational age, time of delivery, and a unique study identifier. After collection, the fresh placentas were refrigerated at 16°C until the investigator processed them. No solutions or fixatives were used.

The processing date and time of each placenta was recorded, and the time between delivery and processing, otherwise referred to as the storage time, was calculated and monitored. The storage time varied from 1 to 114 h, with an average of 29.8 h. Cords were not deliberately cooled or warmed to room temperature, so some were handled warm (fresh) and others were nearly frozen. The mean gestational age of the placentas was 38.8 weeks (range, 35 to 42.4 weeks). From each specimen, the umbilical cord was removed from the placenta at its site of insertion and the cord length and diameter were documented. Cords had an average length of 35.9 cm and diameter of 1.2 cm.

Based on the most likely and previously described mechanisms encountered in the field, each umbilical cord was randomly selected to be severed by one of the following tools or mechanisms: knives (36 cords), scissors (31 cords), traction (19 cords), and crush injury (13 cords). Within each mechanism, different individuals were asked to sever different cords to account for any possible variability in the pattern of the break based on the gender, stature, etc., of the operator. The knives used included a variety of sharp objects, such as surgical scalpels and kitchen knives. Scissors ranged from medical utility shears to household paper

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scissors. For those cords separated by tension or traction, individuals would, by themselves, pull the cord ends in opposite directions or two people would work together in a "tug-of-war" fashion. Crush injury was accomplished by placing the umbilical cord on a hard surface and compressing it with a dull rock or brick until the cord was separated into two pieces. Furthermore, two cords that had been severed with a knife and two that had been cut with scissors were processed as described and then left to air-dry for 7 h before being re-examined.

Immediately after having been separated, the corresponding break ends were aligned, examined, and digitally photographed. After being photographed, a representative tissue section was taken from the severed end, perpendicular to the break surface (i.e., parallel to the length of the umbilical cord). These tissue samples were submitted for routine histologic processing and hematoxylin and eosin stained slides were prepared. All remaining umbilical cord tissue and the previously attached placentas were appropriately discarded.

The gestational age, cord length and diameter, storage time, and mechanism of breakage were charted for each specimen in Microsoft Excel® (Redmond, WA) utilizing their unique study identifier. The digital photographs were uploaded into and stored within a secure database with access limited to the primary investigator.

Results

Thorough examination of the severed cords demonstrated several consistent gross findings for each tool or mechanism studied.

Knives

Cords that were separated by any of the variety of knives used had two severed ends that matched up well with one another and could be re-approximated to resemble the original, intact cord segment. Evaluation of the actual cut ends showed a smooth, flowing cut surface and circumferential margin (Fig. 1). When a sawing motion was utilized, a notching or step pattern was observed, but the break surface and periphery were still smooth and regular (Fig. 2). The cut ends also failed to demonstrate any gross evidence of extravasated blood from the cord vasculature into the surrounding Wharton's jelly. Microscopic examination of the tissue sampled from the severed ends of the cords showed histologically unremarkable umbilical cord.

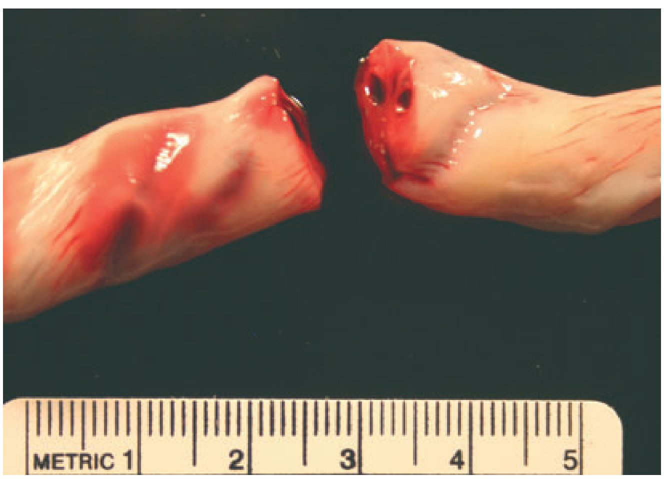

FIG. 1—*Cord cut with a knife, demonstrating characteristic features of matching ends, smooth cut surfaces, and no extravasated blood at the break.*

FIG. 2—*Knife-cut cord with notching.*

Scissors

Similar to what was seen with the use of knives, cords separated by any of the tested types of scissors produced two segments of cord that could easily be re-approximated and matched up with one another. The cut surface and its periphery were smooth and regular with occasional notches similar to those seen in specimens cut by knives. Likely a result of the compressive forces applied while using a pair of scissors, many cords displayed an artifactual retraction of the Wharton's jelly at the break, giving the severed end a concave appearance (Fig. 3). The more structurally sound components of the cord (the amniotic membrane surrounding the outside of the cord and the vessels coursing through it) did not show the same retraction artifact and subsequently appeared to project out from the now-depressed cut surface (Fig. 4). There was also no gross evidence of extravasated blood seen at the break site. Histology demonstrated essentially unremarkable cord tissue.

Traction

In sharp contrast to the matching ends created when an umbilical cord was severed with either a knife or scissors, applying forces in opposite directions to a cord resulted in a break where the

FIG. 3—*Cord separated by scissors demonstrates matching ends and a smooth but slightly concave cut surface.*

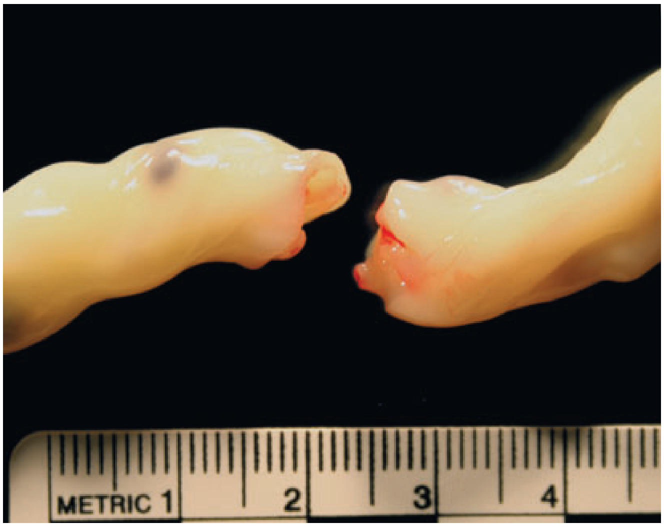

FIG. 4—*Scissors; vessels appear to protrude from retracted break surface.*

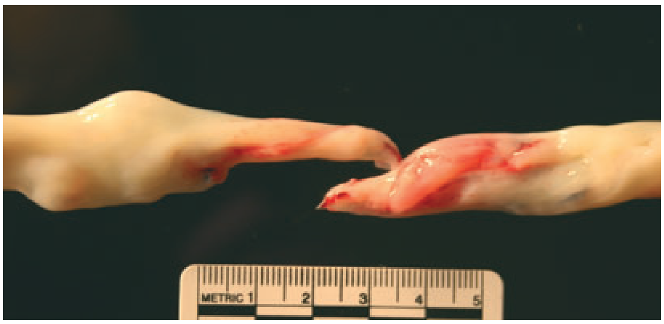

FIG. 5—*Traction; corresponding break ends are irregular.*

FIG. 6—*Traction; tethered, frayed ends with extravasated blood.*

FIG. 7—*Crushed ends demonstrate irregular strands of tissue with focal extravasated blood. Small granules of dirt and sediment are also present, which were transferred from the object used (a rock).*

FIG. 8—*Crushed ends do not mirror one another, and there is a significant amount of extravasated blood.*

corresponding ends were dissimilar and could not be readily re-approximated. Rather than being mirror-images of one another, the break ends were jagged and irregular with no particular pattern compared with its counterpart (Fig. 5). At the site of separation, there was a moderate amount of extravasated blood within the soft tissue of the cord (Fig. 6). This finding was visible grossly as a pink-red discoloration around the broken ends of the cord and was confirmed on microscopic sections.

During the process of separating these cords by traction, considerable variability in the amount of force required to break the cord was noticed. The same individual attempting to tear different umbilical cords would experience significantly different degrees of difficulty from cord to cord. A relationship between the amount of force required to break the cord and the variables recorded (i.e., storage time, gestational age, and cord diameter) was not identified.

Crush

Given the gelatinous and malleable nature of the umbilical cord, a considerable amount of force was required to separate the cord with the use of blunt trauma with a dull object such as a rock. The result of this excessive trauma was two broken ends that were vastly different from one another that could not be reconnected to form the original continuous cord. The ends were composed of fragmented and irregular strands of tissue (Fig. 7). As might be expected, the mechanical trauma endured by the cord at the break site caused the umbilical vessels to rupture and forced the intravascular red blood cells into the surrounding tissue (Fig. 8).

Macroscopically, the ends appeared hemorrhagic and histology supported the gross findings. The amount of extravasated blood seen at the break of the crushed cords was at least comparable to what was witnessed in the cords separated by traction but was frequently greater.

Discussion

The purpose of this study is to establish a solid foundation of information regarding break patterns in umbilical cords for forensic pathologists to use during the investigation of perinatal deaths. While researching the topic, we discovered that there are many published references that discuss the normal and pathologic physical properties of an umbilical cord including its tensile strength (1–7). Morris and Hunt (7) published an article in 1966 that focused on the tensile strength of umbilical cords with only a brief mention of different break patterns based on the tool used. Their descriptions and photographs mirror many of our results, but their usefulness is limited by a small sample size and abbreviated discussion. Our much larger study population, defined methodology, and more detailed descriptions of each break confirm the reproducibility of these findings. This data, in conjunction with a thorough autopsy and investigation, will provide the forensic pathologist with another objective measure to help determine the accurate circumstances surrounding a child's death.

The tools and mechanisms tested in this study represent the majority of the reported means used to sever an umbilical cord and examples of readily available instruments that might be encountered in an actual case. These by no means encompass all possible techniques available for separating the fetus from the placenta, for example, chewing through the cord with teeth. The patterns of such breaks cannot be confidently described without further research.

Other limitations of this study include the exclusion of immature and pathologic umbilical cords. At our institution, most premature, multigravid, and/or clinically complicated placentas are sent to pathology for examination and were therefore excluded from this research. A younger cord (<35 weeks gestation) may be less anatomically and structurally developed than their mature counterparts, and as a result the tissue may respond differently to insult. Similarly, how the tissue would separate if there was an infection (acute funisitis) or structural abnormality (two vessel cord, knot) was not tested and cannot be confidently interpreted based on our findings.

The characteristic features described for each studied tool or mechanism were consistently produced, regardless of the operator, their technique, or the particular tool utilized. Gestational age, cord dimensions, storage time, cord temperature, and air-drying also did not affect the gross appearance of the breaks in the fresh state. Of note, it has been suggested that the patterns of injury might be more readily apparent following formalin fixation (7).

Microscopic sections taken from breaks in all 99 umbilical cords showed no evidence of acute or chronic pathology. With the exception of varying amounts of extravasated blood within the perivascular Wharton's jelly of torn or crushed cords, which corresponded proportionally with the gross findings, histology did not provide any additional information to the study and was considered noncontributory.

The description of extravasated blood in the severed ends of the traction and crushed umbilical cords must be clearly understood as red blood cells that have been physically forced into the perivascular tissue. There was no associated inflammation or evidence of a vital reaction. Only extravasated blood at the study-related break was examined and evaluated. Of important interest, all of the breaks examined in this study were performed postdelivery in a nonvital environment. The presence of blood within the Wharton's jelly should not be immediately interpreted as a vital reaction, suggesting the fetus was viable at the time it was separated from the placenta.

In conclusion, there are gross features to the appearance of a break in an umbilical cord characteristic to the tool or mechanism used to sever it. The two "sharp" tools tested, knives and scissors, consistently produced two matching ends with smooth surfaces and essentially no extravasated blood. The "blunt" mechanisms used in this study, traction and crush injury, yielded broken ends of cords with stranding and fraying of the tissue while also showing moderate-to-significant amounts of extravasated blood. Although it is frequently difficult to distinguish between the different sharp instruments and equally difficult to determine which blunt mechanism was applied, the use of a sharp object can confidently be contrasted from the use of a blunt mechanism.

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