On the Definition of Gestational-Age-specific Mortality

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The “fetuses at risk” concept of gestational-age-specific mortality proposed by Yudkin et al. (Lancet 1987;1:1192–4) and extended by various researchers is becoming popular in perinatal and pediatric epidemiology. However, the definitions using this concept have led to a puzzling phenomenon in which mortality rates appear to increase monotonically with advancing gestational age. While proponents of this concept have highlighted the rationale for using as the denominator the number of fetuses at risk rather than that of fetuses delivered at a particular gestational week, many have not discussed how the numerator is derived. This article reviews various definitions of gestational-age-specific mortality rates. It points out that the definitions based on the concept of Yudkin et al. are indicators of short-term risk only. Furthermore, the seemingly monotonic positive association between mortality rates and gestational age is a misinterpretation. All of the definitions are valid when used and interpreted correctly. The choice of which definition to adopt depends on the specific issues one attempts to address. Calls for abandoning the conventional definitions are not justified.

Abbreviations: SB, number of stillbirths; SBR, stillbirth rate; TB, total number of births.

Seventeen years ago, Yudkin et al. (1) proposed an alternative definition of gestational-age-specific stillbirth rate (SBR), which used as the denominator the total number of fetuses at risk rather than that of fetuses delivered at a particular gestational age. Their definition led to a puzzling phenomenon in which SBRs appeared to increase monotonically with advancing gestational age (1, 2). The last few years saw a sizable amount of research in which this alternative definition of gestational-age-specific mortality was used and extended (3–9). It was shown that not only SBR but also perinatal, neonatal, and infant mortality defined by referring to Yudkin et al.’s concept all increased with advancing gestational age (3, 9). The growing popularity of the “fetuses at risk” concept and the possibility that it can be mistakenly used to justify intervention to shorten gestation are worrying.

In this article, I review the definitions of gestational-age-specific mortality and discuss their properties. All are valid if used and interpreted correctly. Despite its popularity in recent years, the Yudkin et al. definition, together with its extensions, is not more useful than others in addressing medical and public health concerns. The phrase “gestational age specific” will be omitted here for brevity. Furthermore, I use “42+” to represent gestational age at or beyond week 42. Strictly speaking, a rate is a measure of a number of events divided by a number of person-time units exposed to the possibility of the event (10). In contrast, a risk reflects the number of cohort members who have the condition of concern divided by the total number of cohort members. The distinction between the two concepts can be blurred by the fact that sometimes each cohort member contributes one unit of exposure time to the denominator. A rate may look like a risk because the denominator, say, “100 persons × 1 week,” may be written as “100” and be mistaken as “100 persons.” In the literature, the terms “rate” and “risk” have been used inconsistently. In this article, I draw a distinction between them when the scientific context requires. Otherwise, they are interchangeable.

THE CONVENTIONAL AND YUDKIN ET AL. DEFINITIONS

The conventional definition of SBR at week $i$ of gestation (SBR$_i$) is

$$SBR_i = \frac{SB_i}{TB_i},$$

where $SB_i$ is the number of stillbirths at week $i$ of gestation, and $TB_i$ is the total number of births at week $i$ of gestation.
The comparability issue would not have occurred if Yudkin et al. had used the strict definition of “rate.” Since the Yudkin et al. numerator counts the SB occurring in a 2-week period, the exposure time that each fetus contributes is up to 2 weeks; that of a fetus stillborn or liveborn at week \( i \) or \( i + 1 \) is on average about 0.5 week (or 1.5 weeks), and that of a fetus delivered at or after week \( i + 2 \) is 2 weeks. A strictly defined rate for week \( i \) should use
\[
TB_i \times 0.5 \text{ week} + TB_{i+1} \times 1.5 \text{ weeks} + \sum_{j \geq i+2} TB_j \times 2 \text{ weeks}
\]
for the denominator. Similarly, the denominator of the revised Yudkin et al. definition can be changed to
\[
TB_i \times 0.5 \text{ week} + \sum_{j \geq i+1} TB_j \times 1 \text{ week}
\]
no reflect the fact that the numerator includes only deaths in 1 week. If this approach had been used, the Yudkin et al. SBR and the revised Yudkin et al. SBR would have been mathematically comparable.

It is important to emphasize that the Yudkin et al. definition and its revision are estimates of the short-term SBR, not overall SBR, for fetuses at risk at a given gestational week. At any week of gestation, a fetus may move to one of three conditions: 1) stillbirth, 2) livebirth, or 3) remaining undelivered and proceeding to the next week of gestation. The third condition does not represent an outcome; the outcome awaits further evaluation at later gestational weeks. Table 1 shows the numbers of stillbirths, all births, and fetuses at risk at different gestational ages for singleton births in Canada during 1991–1997. At week 41, for example, 296,494 (245,969 + 50,525) fetuses were at risk of stillbirth. The SBR at this gestational age was 304, giving an SBR of 1.025 (per
1,000) according to the revised Yudkin et al. definition. As shown in this table, the revised Yudkin et al. definition produced SBRs that increased with higher gestational age. However, 92 of the 296,494 fetuses at risk at week 41 were stillborn at week 42+. Therefore, the overall SBR of the fetuses at risk at week 41 had a numerator of 396 (304 + 92), giving a result of 396/296,494 = 1.336 (per 1,000).

**FELDMAN’S DEFINITION**

Feldman (12) proposed including in the numerator the number of all stillbirths at or beyond week $i$ of gestation to calculate the SBRs of fetuses at risk at week $i$:

$$\text{Feldman SBR}_i = \frac{\sum_{j \geq i} \text{SB}_j}{\sum_{j \geq i} \text{TB}_j} \times \frac{\sum_{j \geq i} \text{SB}_j}{\sum_{j \geq i} \text{TB}_j}.$$  

Feldman’s definition is correct in estimating the overall SBR of fetuses at risk, but the Yudkin et al. definition and its revision are not. As shown in table 1, Feldman’s definition gave the familiar pattern of SBRs declining with advancing gestational age, followed by an upturn in the postterm period. All three definitions in table 1 converged on the same value for the highest category of gestational age.

**EXTENSIONS TO YUDKIN ET AL.**

Hilder et al. (3) extended the revised Yudkin et al. definition to calculate neonatal, postneonatal, and infant mortality. For instance, the number of newborns who are delivered at week $i$ and who die during the neonatal period is used as the numerator, with the number of fetuses at risk at week $i$ as the denominator, to give a neonatal mortality rate. This method has been used in several recent studies (4–6, 8, 9). While the conventional definition of neonatal mortality includes in the denominator only the number of liveborn infants, the extensions of the Yudkin et al. definition include the number of stillborn infants in the denominator as well.

**DOES MORTALITY INCREASE MONOTONICALLY WITH GESTATIONAL AGE?**

That mortality monotonically increases with gestational age is a misinterpretation. The relation between the Feldman and the revised Yudkin et al. definitions can be seen by a little manipulation of formulae. First, multiply both the numerator and the denominator of the revised Yudkin et al. SBR by the sum of all stillbirths at or beyond gestational week $i$ (which leaves the value unchanged), and then rearrange the positions of the components, as follows:

$$\text{Revised Yudkin et al. SBR}_i = \frac{\sum_{j \geq i} \text{SB}_j}{\sum_{j \geq i} \text{TB}_j} \times \frac{\sum_{j \geq i} \text{SB}_j}{\sum_{j \geq i} \text{TB}_j}.$$  

It is clear that the revised Yudkin et al. definition is a product of two components. The first is the Feldman SBR; the second is an “immediacy factor.” This factor indicates the proportion of stillbirths occurring at or beyond gestational week $i$ that occurs immediately at week $i$. As shown in table 1, this factor ranges from 0 to 1 and increases with advancing gestational age. In the preterm period, there is more scope for stillbirths to occur later, and the value of the factor is small. In the highest category of gestational age (42+), there is no scope for further postponement and the factor must have a value of 1. In relation to this immediacy factor, the value of the Feldman SBR is small and has to be expressed as incidence per 1,000 fetuses. The revised Yudkin et al. definition is therefore dominated by this immediacy factor and shows a monotonic increase in relation to higher gestational age. A similar derivation and comment apply to neonatal and infant mortality rates defined in reference to Yudkin et al. They do not indicate that mortality among fetuses at risk is lower in the preterm period than in the term period. They indicate simply that in the preterm period, death is less imminent.

**CONCLUDING REMARKS**

All definitions are correct; some are more useful in certain circumstances. The definitions reviewed above describe different aspects of mortality. None is superior to the rest in all circumstances. Yudkin et al.’s criticism that the conventional definition of SBR was misleading was not justified (1). Neither was the criticism against public health agencies that reported the conventional statistics (13). The Fetal and Infant Health Study Group of the Canadian Perinatal Surveillance System made an effort to justify using the number of fetuses at risk as the denominator (9), but they did not discuss the fact that the numerators (of the revised Yudkin et al. definitions) they used indicated short-term risks only.

The choice of methods depends on the specific issues being studied. For example, one may want to investigate the impact of advances in neonatal medicine on caring for preterm newborns, which refers to the actual gestational age of the newborns, not the gestational age at which they are exposed to risk. Furthermore, only liveborn babies are “at risk” of receiving the care to be studied. The conventional definitions of neonatal or infant mortality are required to address this issue. As another example, a researcher may want to pay special attention to the stress of labor and intrapartum death. The conventional definition of SBR is more
relevant because only those fetuses that are delivered experience the stress.

Hilder et al. commented that the conventional definition was “often used as the basis for the conservative management of prolonged pregnancy” (3, p. 172) because it usually indicated only a marginally higher level of mortality after gestational week 40. They proposed use of the revised Yudkin et al. definition in clinical decision making. In this context, Feldman’s definition, which takes account of the overall risk, is more appropriate than what Hilder et al. suggested. A mother cares about the final outcome of her pregnancy, not the short-term risk in a segment of the pregnancy. Table 1 shows that both Feldman’s and the conventional definitions indicated only a small increase in SBRs after 40 weeks of gestation. These definitions would not lead to different management decisions. With the long-term welfare of fetuses in mind, those estimates of short-term risks have limited value.

Yudkin et al. (1) maintained that obstetricians need to know the possibility of fetal death in a short time interval in the near future. While I doubt the generality of this statement, it is true that in the management of prolonged pregnancy, the obstetrician must repeatedly assess the well-being of and the risk faced by the fetus in the immediate future (14, 15). In this context, the revised Yudkin et al. SBR may have some practical utility. However, such assessments may need to be conducted more frequently than once a week. A reference period of 2 weeks (Yudkin et al.) or 1 week (revised Yudkin et al.) may be inappropriate. A strictly defined rate using a fraction of a week for the time frame should be more appropriate.

The examples I have provided are not meant to be exhaustive, and the discussion here may not cover all relevant perspectives. For instance, perhaps the frailty of a fetus affects the timing of delivery, not the other way around. Whether such reverse causation affects the relative merits of the definitions is not yet clear. The utility of the various definitions of gestational-age-specific mortality remains to be seen and discussed further. The point of this article is that there is no justification for regarding any of them as right or wrong without careful consideration of the context involved.

REFERENCES