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The uses of epidemiology in the evaluation of regional perinatal services

I shall discuss, in this presentation, the principles and concepts that ought to underly the regionalization of perinatal medical services, drawing upon my experiences in assessing such services in two different settings in the United States – the City of New York and the State of Michigan. Where possible, vital data from Switzerland, kindly forwarded to me by Dr. Adrien Moessinger, will also be used for illustrative purposes.
Two major concepts will be emphasized in this talk:

– Almost everything we need to know about the effectiveness of the provision of medical care to all mothers and infants in a region can be obtained from routinely collected vital data. There is little need for special studies if the vital data system regularly collects the needed data.
– Much of what we do in assessing regionalization of health services constitutes an exercise in geographical or spatial epidemiology. The major issues are distances between people and hospitals, the movement of people and the provision of services in spite of geographical barriers to access.

Regionalisation of perinatal services is needed because the newborn intensive care technology that has been developed over the last 20 years is very effective, and has been shown in several population-based studies, including our own in New York City, to make a profound difference to the risk of mortality in low birthweight infants[1–4]. As a result of these technologies, mortality has declined substantially in recent years for low birthweight babies both in the United States and in Switzerland, not just in centers of excellence but in the entire population (Table 1). Current birth-weight-specific mortality rates are quite comparable in both countries, with the exception of the smallest birthweight category. This latter difference may reflect a more humane and sensible approach to the least viable babies in Switzerland than in the United States.
At the same time, resources are too limited to permit intensive care services to be provided in every hospital. These services must be concentrated in a few select hospitals, and this is where the difficulty lies, because every baby in need should have access to life-saving technologies. The major task of regionalization of services, then, is to make

Comparison of birthweight-specific neonatal mortality (per thousand live births) USA and Switzerland

Birthweight in grams*	USA white population, 1983	Switzerland total population, 1982–85
501–1000	538.8	653
1001–1500	154.1	164
1501–2000	52.2	56
2001–2500	15.4	13
2501–3000	3.9	3.1
3001–3500	1.5	1.7
3501–4000	1.1	1.4

* Swiss data: 500–999 g, 1000–1501, etc.

Table 1. *Birthweight-specific mortality, USA and Switzerland.*

sure that babies in need of intensive care get it. A secondary, but nonetheless important goal, is to facilitate the most efficient use of resources, i.e. to try to avoid providing high-technology care to infants not in need.[5]

In New York City, we were unable to show any differences in mortality by hospital of birth for infants born at term (≥ 37 weeks) and of normal weight (≥ 2250 g).[6] This group of infants constituted 86% of all births in New York City, emphasizing that regionalization efforts must consider not only sick babies, but also the majority of babies who will experience a healthy delivery with no special problems. I am convinced that a low technology setting, such as a midwife-run delivery service would do very well with most babies, if coupled with adequate screening for risk both before and after birth.

Screening first takes place prior to birth, with babies at high risk of mortality assigned for delivery at hospitals with intensive care units. The most important screening point is at the onset of labor, and the most important information to obtain is gestational age. Babies who are going to be born prematurely must deliver in hospitals with newborn intensive care units. Since it is sometimes difficult to establish gestational age, and since labor is sometimes only diagnosed at advanced stages, we must also screen again after birth, and have mechanisms available to transport sick infants from community hospitals to intensive care units. Babies who weigh 1500 g or less at birth, referred to as very low birthweight (VLBW) babies, are all in need of newborn intensive care. Since data on birthweight are commonly available, the distribution of these infants in different kinds of hospitals can be easily determined, and is often used as an indicator of regionalization.

Four fundamental questions should be asked about any perinatal regionalisation system. The first two are so basic that we do not often stop to ask them.

Where are the sick babies located?

Infants at high risk of dying may not be evenly distributed in the region, and may be concentrated in certain areas.

Where are the newborn intensive care units located?

Are these units in the same location as the sick babies, or are they in different locations? A simple geographic plot of the numbers and rates of VLBW births by county, township or other geographic unit, and a simultaneus mapping of the newborn intensive care units, will quickly reveal how good is the geograhic match of hospitals and babies.

The next two questions have to do with the screening process.

Where are the sick babies born?

Are they born in the right place? Because we must try to maximize the proportion of VLBW infants who are born in intensive care units, the proportion of them born in hospitals with intensive care units is a key measure of the effectiveness of prenatal screening and maternal referral.

Where do the sick babies die?

In almost all circumstances, no baby should die in a hospital that does not have intensive care facilities. The proportion of regional neonatal deaths that take place in hospitals with newborn intensive care units is therefore a measure of the effectiveness of post-natal screening and infant transport.

I should emphasize that the data generated to respond to these questions are sometimes only the first step in assessing regionalization. Unusual regional variations, excess mortality in one location, apparent lack of access in another, should prompt detailed investigations at the local level.

The locations of hospitals by type of service available is easily ascertained. The number of births at each birthweight, the place of birth, and the place of death are readily available in vital data in the United States. With knowledge of these parameters, no special study is needed to make an effective assessment of the extent of perinatal regionalization.

Let me know turn to some specific examples of how one might assess regionalization.

Table 2 illustrates the contrasts between the three regions under discussion today. New York City, Michigan and Switzerland each present a different kind of regionalization problem. In New York City, seven million people are squeezed into 365 square miles, for a population density of over 19000 per square mile. Michigan, by contrast, covers almost 60000 square miles (about the size of England)

	New York City	Michigan	Switzerland
Area:	365 sq. miles	58257 sq. miles	15941 sq. miles
Population:	7.02 million	9.24 million	6.49 million
Density:	19233/sq. mile	158/sq. mile	407/sq. mile

Table 2. *Three populations: NYC, Michigan, Switzerland.*

and has a population of about 9 million, yielding a population density of 168 per square mile. Switzerland lies somewhere between these two extremes with 6.5 million people in 116000 square miles.
Figure 1 shows a map of Switzerland with different levels of infant mortality indicated in different shades of gray. Regional variations in infant mortality are present even in Switzerland, and I am sure that you are much better equipped to interpret the meaning of these differences than am I. It should be noted, however, that the highest infant mortality in Switzerland is a quite low infant mortality by international standards. The next step would be to see where the intensive care units are located in relation to these differences in infant mortality.
Switzerland also has differences in both stillbirth mortality and infant mortality by ethnic group, with the highest rates found in the Turkish population (Figure 2). It is possible that these ethnic differences are linked to be geographic variations shown in Figure 1. In the USA, there is a strong correspondence between ethnicity and infant mortality, and regions of our country which have large African-American populations are usually in greater need of perinatal intensive care services than are other regions. Planning for placement of hospitals should therefore take account of regional and population variations in risk of perinatal death.
Michigan is geographically unique among the states, as it is the only state composed of two peninsulas (called the lower and the upper) (Figure 3). The lower peninsula is bordered by the states of Ohio and Indiana in the south, and the upper peninsula by Wisconsin in the west, but the longest borders of the state are constituted by four of the five great lakes: Michigan, Huron, Erie and Superior. This geography makes for considerable isolation, and only a few mothers and infants

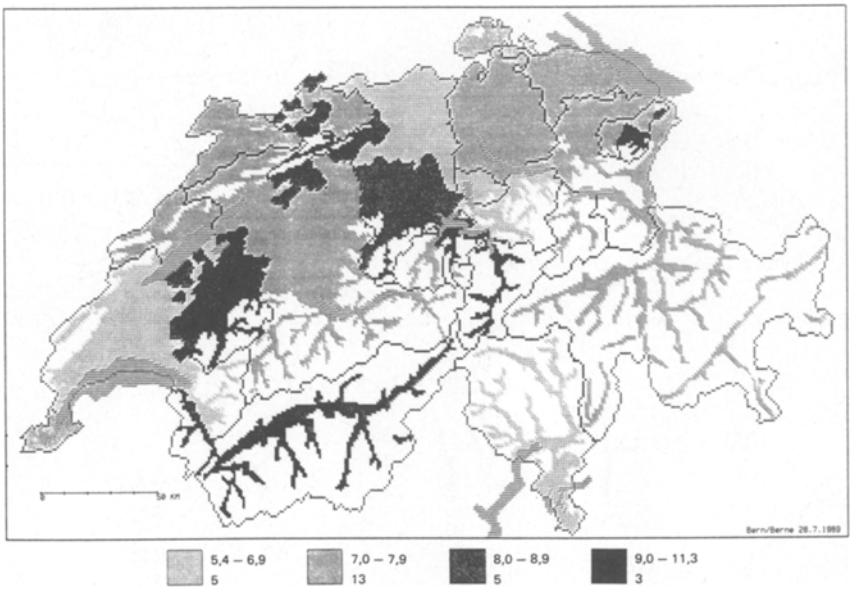

Figure 1. *Geographic variations in infant mortality in Switzerland. Source: Bundesamt für Statistik. Totgeburten und Säuglingssterblichkeit in der Schweiz 1982 – 1985, Bern: BFS, 1990: 27, Fig. 14.*

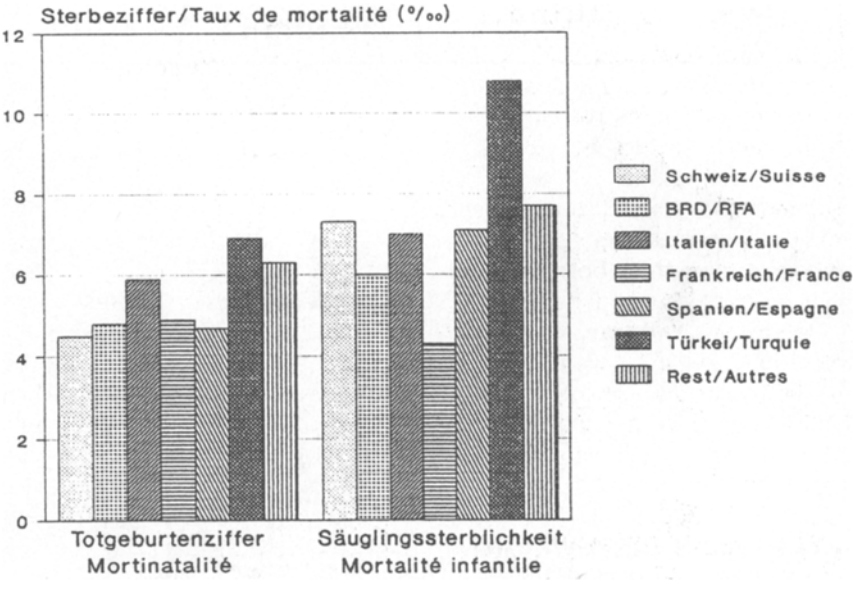

Figure 2. *Ethnic variations in infant mortality in Switzerland, 1982 – 1985. Source: Bundesamt für Statistik. Totgeburten und Säuglingssterblichkeit in der Schweiz 1982 – 1985, Bern: BFS, 1990: 33, Fig. 22.*

leave the state for perinatal medical care. It also makes for great distances. For example, it is a longer drive from Detroit to Copper Harbor (the northernmost point of the upper peninsula), than it is from Detroit to Washington, D.C.

Of the 9 million inhabitants of Michigan, 8.75 million live in the lower Peninsula, and only 250000 in the very scenic and primeval Upper Peninsula. Most of Michigan's population is concentrated in the south-west corner of the state,

Figure 3. *Map of Michigan showing its two peninsulas.*

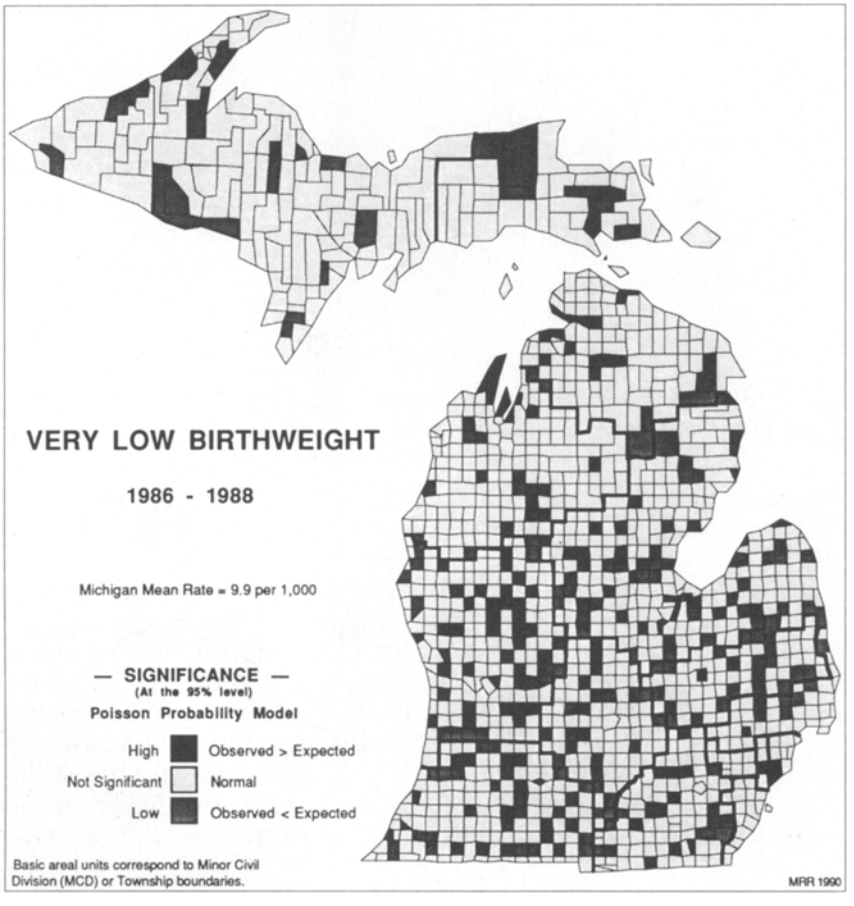

Figure 4. *VLBW rates by minor civil division, Michigan, 1986 – 88.*

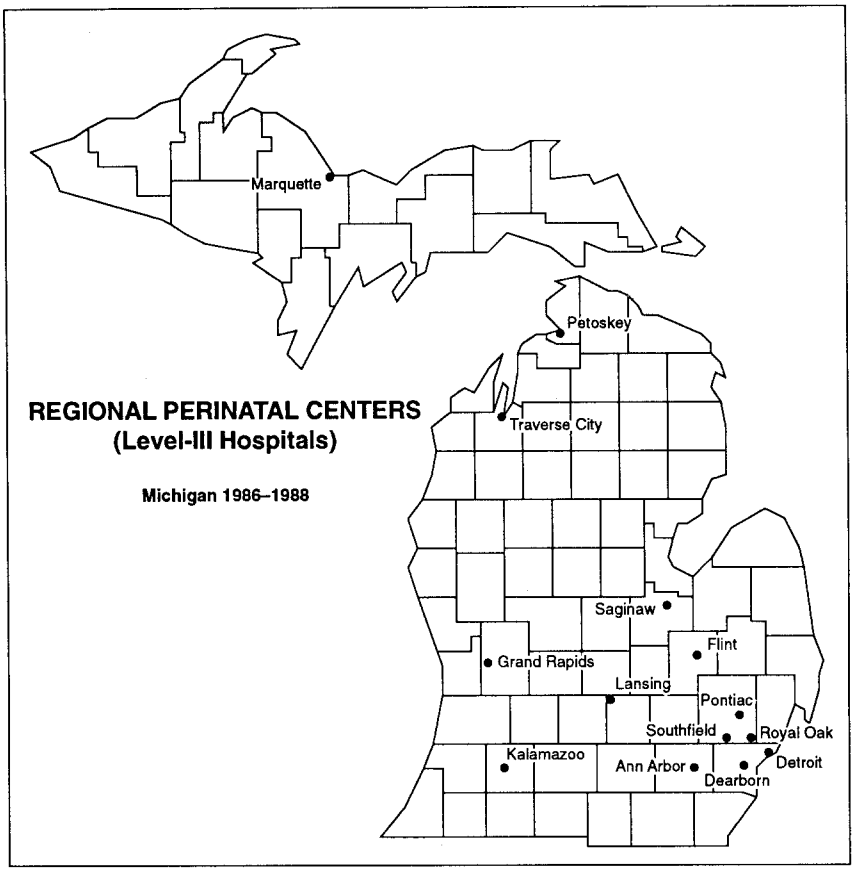

Figure 5. *Hospitals with Newborn Intensive Care Units in Michigan.*

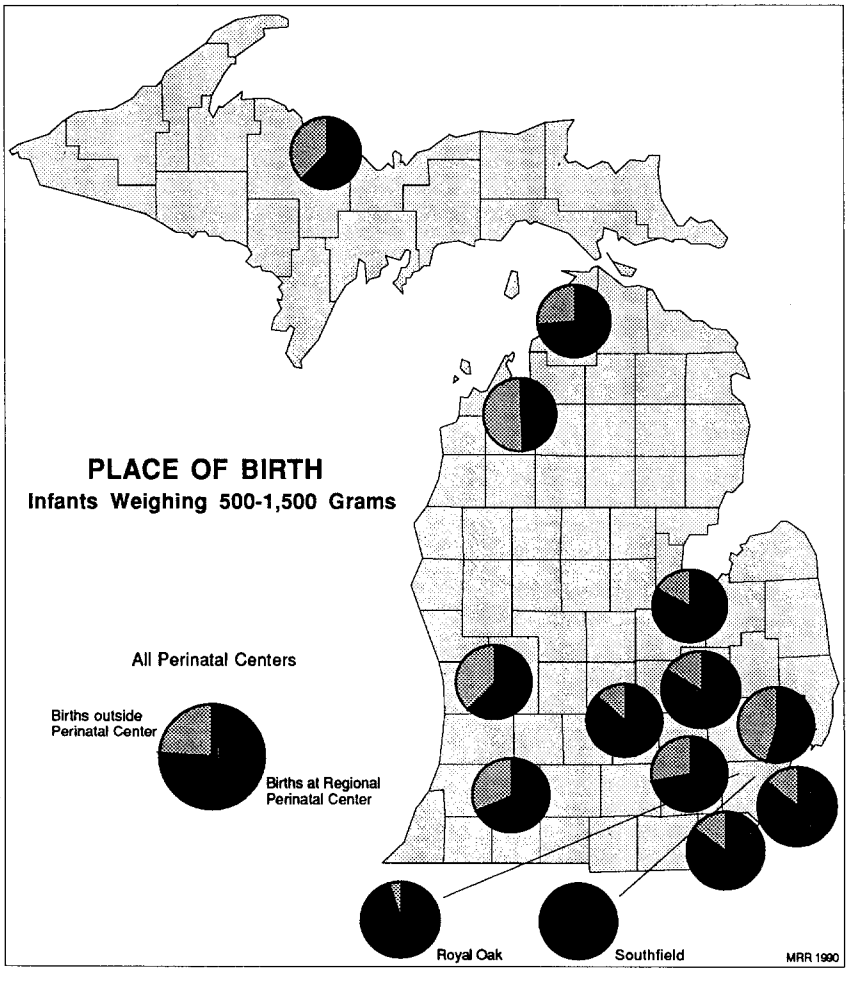

Figure 6. *Place of birth of VLBW infants in Michigan.*

where about four million people live in the Greater Detroit Metropolitan Area. This uneven population distribution poses severe problems for the delivery of perinatal services.

Michael Rip and I have plotted the data called for in the four questions I listed above according to Michigan "minor civil divisions" or townships (which we will refer to here as "towns" for brevity) which number about 1200 in the state. As you can see, the rate of VLBW birth is highest in certain MCD's, which correspond to the cities of Detroit, Flint, Saginaw and Muskegon, all of which have large African-American populations. The sparsely populated and largely Caucasian upper peninsula has relatively low VLBW rates.

Of the 140 hospitals that deliver babies in Michigan, 17 are licensed NICU's. Of the 17 NICU's, four are in the city of Detroit, and another five are located in the suburban Detroit area. Thus the higher population density and the higher risk of VLBW in Detroit is addressed by the location of NICU's. Each of the five medium sized cities in the southern part of Michigan also has hospital with an NICU. The remaining three units are in two smaller towns in the northern part of the lower peninsula, and in one upper peninsula town.

For each of the 17 NICU's, we have designated a service region, defined as all towns for whom the town containing the NICU is the nearest in terms of road travel time, as determined by the state department of transportation. Within these 17 regions, we can assess the effectiveness of regionalization by looking at place of birth and place of death. We ask the question, of an entire regions' VLBW births, what proportion are born in NICU's?

Figure 6 illustrates the proportion of VLBW births born in NICU's in each of the 17 perinatal regions of Michigan. In each of the pie diagrams in the figure, the black part of the pie indicates the proportion of all of the region's births under 1500 g that take place in regional centers. In Detroit and its suburbs, all VLBW births in the region take place in the regional center. This centralization of VLBW births could represent effective prenatal screening, but more likely indicates good placement of NICU's in urban areas where risk of VLBW is high. The lowest figure proportion, about 50%, is found in one rural region. For the state as a whole, a remarkable 76% of all births under 1500 g are born in a regional center, one of the best figures for any region of the USA[7], the geographical barriers alluded to before notwithstanding.

For example, in New York City in the late 1970's only 36% of births under 1500 g took place in a hospital with an NICU, and by 1983, this figure had improved only to 43%, lower than the lowest figure for any of the 17 regions of Michigan. Thus, easy geographical access to NICUs does not necessarily indicate that babies will deliver there. In fact the relative ease of postnatal transport to an NICU in a metropolitan area may perhaps discourage antenatal screening and referral for delivery.

To assess the effectiveness of postnatal transport, we examined the place of death for infants dying in the first week of life. Since age of death is available on death certi-

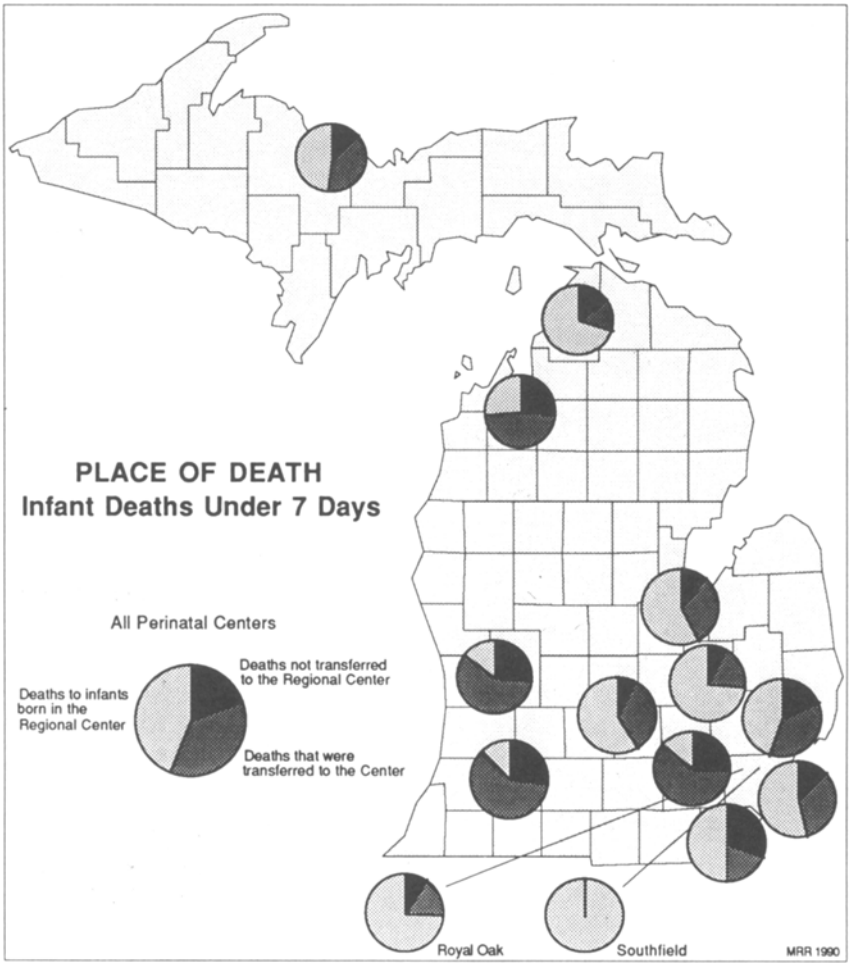

Figure 7. *Place of death for infants in Michigan.*

ficates, and since both hospital of death and hospital of birth are recorded, one can ascertain whether a baby died in an NICU, and also whether the baby was born there or transferred there from another hospital.

The pie diagram is divided in this figure into three sections, representing regional deaths occurring outside NICU's, and for regional deaths within NICU's, those born in the same hospital and those transferred in (as indicated by discordant hospital of birth and death). A more detailed assessment is possible looking separately at different post-natal ages of death, but here we show all first week deaths. We have shown, for example, that in New York City, infants who die in the first four hours of life are virtually never transported[8].

The figure shows that most infants die in intensive care units, though a non-trivial minority do die in hospitals without NICU's. When we looked at this in more detail, we found that some Detroit hospitals were offering intensive care services, even though the state had not designated them as intensive care hospitals, and also that some babies not transferred had lethal anomalies or were extremely immature.

I will now draw your attention to two items of information from Swiss vital data that may possibly provide some information about regionalization of perinatal services in your country. One observation is that mortality for VLBW infants differs somewhat by canton (Figure 8). This variation is not large, but might prompt you to look at the availability of NICU services in the higher mortality cantons.

Another interesting analysis performed by your vital statistics department is to assess infant and stillbirth mortality by hour of birth (Figure 9). Some years ago, Tyson et al,[9] showed that hospitals with NICU's did not experience as much

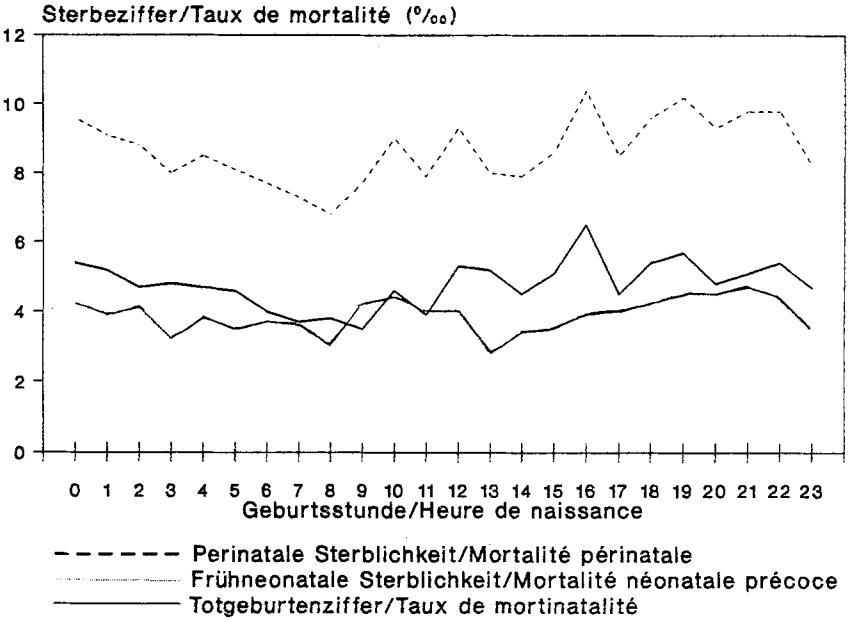

Figure 8. *Mortality by birthweight in Swiss cantons, 1982–1985.*
Source: Bundesamt für Statistik. Totgeburten und Säuglingssterblichkeit in der Schweiz 1982–1985, Bern: BFS, 1990: 30, Fig. 18.

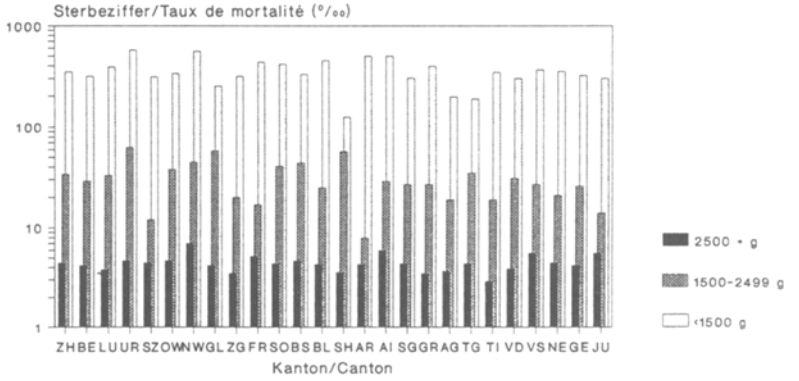

Figure 9. *Variation in mortality in Switzerland by hour of birth, 1982–1985.*
Source: Bundesamt für Statistik. Totgeburten und Säuglingssterblichkeit in der Schweiz 1982–1985, Bern: BFS, 1990: 32, Fig. 20.

variation in mortality by hour of birth as did hospitals without special facilities. In the latter type of hospital, there is often excess mortality in the middle of the night, when staffing is at its lowest. Figure 9 suggests some diurnal variation in mortality in Switzerland, though the times of highest mortality are not the night-time hours. Whether this variation can be linked to newborn intensive care would require further study.

In conclusion, from several simple and usually readily available items of vital data it is possible to learn a great deal about the workings of a regionalised system for perinatal care. The key pieces of information are:

– The locations of the newborn intensive care units and their proximity to populations of risk.
– The proportion of births under 1500 g which take place in hospitals with NICU's.
– The proportion of infant deaths which take place in hospitals with NICU's, and the proportion of those deaths who had been born in the same hospital.

An additional issue of public health importance, not addressed in this talk, is the access time to the NICU of the population resident in population centers. The means of transportation for mothers and infants within a region, be they road transport or rotary or fixed wing aircraft, need to be enumerated and assessed in terms of their effectiveness. The latter must reflect the total time for the transport process from the point of patient origin to the final destination.

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