

Neonatal Intensive Care Units: Is the Level of Utilization Still Paralleled by Infant Mortality?

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Santos-Eggimann B (Health Services Research Division, University of Lausanne, Institute of Social and Preventive Medicine, 17 rue du Bugnon, CH-1005 Lausanne, Switzerland) and Shapiro S. Neonatal intensive care units: Is the level of utilization still paralleled by infant mortality? *International Journal of Epidemiology* 1994; 23: 528-535.

Background. This research investigated the relationship of maternal place of residence with the utilization of neonatal intensive care units (NICU) and whether maternal residence was related to infant mortality in two contiguous Swiss cantons, Vaud and Valais, relying on the same tertiary NICU. Previous works have shown that infant mortality is close to the Swiss rate in Vaud, but elevated in Valais.

Methods. Analyses were based on linked birth and death certificates relating to the 57 962 single livebirths to mothers resident in Vaud or Valais delivered in hospitals over the 1979-1985 period. Data on utilization were retrospectively collected from NICU admissions' registers and linked to birth certificates.

Results. Results of logistic regression models pointed to a large difference for all birthweight groups, in NICU utilization between Vaud and Valais after adjustment for risk factors abstracted from the birth certificate, when tertiary NICU beds were considered. When the definition of NICU utilization was enlarged to all beds of an identified NICU, irrespective of the location of the unit and of the intensity of care provided to admitted newborns, there was a clear reduction in geographical variations. Neonatal and infant mortality were significantly higher in the lower NICU utilization region only among newborns weighing ≥ 2500 g at birth.

Conclusions. We found no difference in infant mortality (odds ratio 1.0) among < 2500 g newborns residing in regions characterized by a large difference in tertiary NICU utilization. Nevertheless, the limited sample size did not permit specific analyses of lower birthweight (e.g. < 1500 g) newborns. Replication of such research in other settings based on larger samples is needed.

Neonatal intensive care expanded quickly in teaching hospitals during the 1960s and is generally considered to be a major contributor to the marked decrease in infant mortality, especially among low and very low birthweight newborns.¹⁻⁶ This followed a 10-year period during which the infant mortality rate had remained largely unchanged.⁷ From the 1970s, many states and countries developed recommendations for the regionalization of perinatal care⁸⁻¹³ driven by the need to allow access to neonatal intensive care units and concern for the costs generated by such care.¹⁴

The success of perinatal care regionalization pro-

grammes has often been measured by the increased proportion of high-risk births in a given region admitted to tertiary neonatal units, and an associated fall in infant mortality rates observed mainly during the neonatal period.¹⁵⁻¹⁸ Nevertheless, preoccupation with postponement of death^{19,20} rather than avoidance as a possible undesired effect of neonatal intensive care has justified monitoring death rates beyond the first month of life. Although mortality rates fell with the regionalization of perinatal care, the largest and best-designed studies devoted to the evaluation of regionalization programmes in the late 1970s failed to demonstrate differences in mortality rates between specially designed programme areas and comparison regions. This was due to an increase in the level of tertiary care utilization observed in geographical areas not covered by such programmes.^{16,17}

In Switzerland access to neonatal care is theoretically homogeneous because of the small size of the country, the ubiquitous availability of relevant hospital equipment and health insurance coverage for 98% of the general population. In addition, neonatal care provided to residents is reimbursed by social security. Health care is organized by the 26 politically independent cantons.

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Previous work has demonstrated variations in infant mortality between cantons, which were not explained by demographic differences such as birthweight or maternal age distributions.²¹⁻²³

Local concern for these variations in mortality and a lack of knowledge of neonatal care regionalization led to a request from the health departments and clinicians to study the situation in two contiguous cantons, Vaud and Valais. These cantons were selected because of the higher infant mortality observed in Valais and the fact that, for geographical reasons, both cantons rely on the same neonatal intensive care unit (NICU) for tertiary care. The research addresses the following questions:

- 1) What is the level of use of NICU in Vaud and Valais; is it independent of the maternal place of residence?
- 2) What are the characteristics of the infant mortality differential observed between Vaud and Valais?
- 3) If the use of NICU is found to be different in Vaud and Valais, do infants in the higher use region experience lower mortality?

POPULATION AND METHODS

Population and Organization of Neonatal Care

Vaud and Valais are neighbouring cantons, lying largely to the north and east of Lake Léman along the river Rhône (Figure 1).

In Vaud the population density is highest on the shores of Lake Léman where the city of Lausanne is located. Lausanne accounts for one-third of the population while the other major cities of Vaud have between 10 000 and 25 000 inhabitants. Over the study period, 18 maternity centres were available in Vaud covering the eight geographical health areas. The University Hospital Centre in Lausanne has the largest maternity centre and an NICU. The Lausanne NICU includes 14 beds for very intensive or continuous care and 10 beds for specialized care. Staffing levels are 1 nurse/bed for very intensive care, 1 nurse/2 beds for continuous care, and 1 nurse/3 beds for specialized care. The unit is a training centre in neonatology and fulfils the conditions for recognition by the Swiss Society of Intensive Medicine.

The population of Valais is mostly located in the Rhône Valley along which cities of 10 000 to 20 000

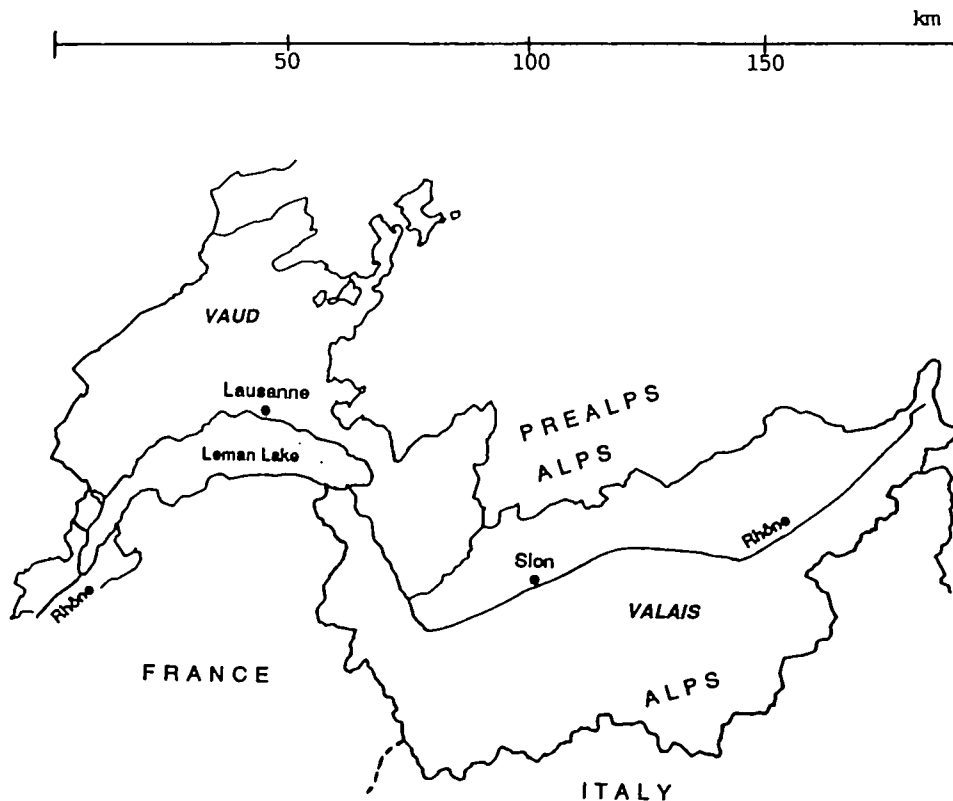


FIGURE 1 Outline map of Vaud and Valais (Switzerland)

residents are situated. Valais is divided into six health areas of at least 25 000 inhabitants, each served by a public hospital with obstetric services. In addition, two private clinics provided maternity services over the study period. Public health department policy permits the use of facilities in other cantons for cases requiring highly specialized techniques or equipment. For neonatal intensive care, the closest tertiary centre is Lausanne (Vaud), but some cases may be referred to tertiary centres in Bern and Geneva. Despite this policy, the hospital in Sion (Valais) has set up a NICU with five beds, including two equipped for mechanical ventilation. It is part of the paediatric ward which is headed by physicians trained in neonatology. Staff on the unit are attached to the general paediatric ward and their levels depend on occupancy of the unit. Although it is not recognized as a referral centre by the Valais department of public health, the unit in Sion is available for transfers from other maternity departments.

Data Sources and Definition of Variables

Linked birth and death certificates provided by the Federal Office for Statistics are the primary data source for this study; the format for the whole country is the same. All single livebirths delivered in hospitals to Vaud and Valais residents registered during the 1979–1985 period were included in the study. Information on birthweight was first recorded on birth certificates in 1979, and linkages could not be performed for births in years later than 1985 because of changes in the certification forms between 1986 and 1987.

A file, derived from hospital records, of all births to Vaud and Valais residents admitted to NICU in Lausanne, Bern, Geneva and Sion, was then linked to the vital statistics.

Explanatory and control variables were abstracted from birth certificates. They include birthweight, sex, maternal age (<20, 20–34, ≥35 years), mother's marital status (currently married or not), parental socio-economic status (defined from father's profession for births to married mothers and from mother's profession otherwise, based on Beer's six-category classification²⁴) and newborn's nationality (Swiss or foreign). For the subgroup of births to married mothers, additional variables such as birth order (1, 2 or 3, ≥4) and short (<1 year) livebirth interval were also available. Other variables such as gestational age or birth defects are not recorded on Swiss birth certificates. All control variables were defined either as dichotomous or as dummy variables, except birthweight which was categorized into 250 g categories from 500–749 g to ≥4000 g.

The explanatory variable, maternal residence, was first categorized into Vaud or Valais. However, some

population differences were noted between Vaud and Valais because Lausanne is larger, has a University and a major teaching hospital, and also had a higher proportion of older mothers, unmarried mothers, foreign newborns, etc. For this reason, comparisons were repeated between Valais and Vaud after excluding births to residents of Lausanne.

Use of an NICU as a dependent variable was first defined as the admission to the very intensive or continuous care subunits of the NICU in Lausanne or to the NICU located in the teaching hospitals of Bern and Geneva (use of tertiary care). Analyses were then performed with a broader definition of NICU use covering all admissions to the NICU in Lausanne, Sion, Bern and Geneva (secondary or tertiary care). Mortality as the other dependent variable was defined first as death occurring during the first 28 days of life (neonatal death) and then during the first year of life (infant death).

Data were complete except for birthweight (missing in 23 cases) and for the socio-economic status (missing in 27 cases).

Analytical Approach

Analyses of the relationship between maternal residence and NICU use, or mortality, were performed independently using logistic regression models to control for risk factors abstracted from the birth certificate. They were carried out separately for all births and then for normal birthweight (≥2500 g) and for low birthweight (<2500 g, <2000 g) newborns. The procedure used for logistic regressions was the LOGISTIC of SAS.

All potential risk factors were first included in exploratory models of neonatal and infant mortality. Variables retained in either of the two models at the $P < 0.1$ level in a stepwise logistic regression were considered as control variables (Wald χ^2 on regression coefficients). Higher orders of the birthweight category (square, etc.) and interactions between birthweight and other variables were also considered. Interactions were retained when they reached the $P < 0.05$ level. Control variables were then included in logistic regression models of the relationship between maternal residence and either NICU utilization or mortality. The resulting models can be summarized as:

$$\text{logit}(p) = \log(p/(1-p)) = \alpha + \beta_1 x_1 + \sum_{j=2}^q \beta_j x_j$$

and $p = \text{Pr}(Y = 1 / x_1, x_2, \dots, x_q)$

where $Y = \text{NICU use (or death)}$, $x_1 = \text{maternal residence}$, $x_2, \dots, x_q = \text{control variables found associated with either neonatal or infant mortality in stepwise logistic regression}$.

TABLE 1 *Livebirths in Valais and Vaud 1979-1985*

	Maternal residence		
	Valais	Vaud	Vaud excl. Lausanne
Livebirths	20 202	39 153	26 550
Single livebirths	19 821	38 356	25 984
Single livebirths delivered in hospitals			
No.	19 775	38 187	25 855
% <2500 g	4.7%	4.8%	4.5%
% <2000 g	1.3%	1.4%	1.3%

The odds ratio (OR) was used as measure of association. Adjusted OR and their 95% confidence interval were derived²⁵ from the regression coefficients associated with maternal residence (β_1).

Analyses were performed on all single livebirths delivered in hospitals. They were repeated on the subset of births to married mothers; this subgroup was slightly less numerous but could be studied with additional control variables such as birth order or livebirth interval, and a higher level of homogeneity regarding socio-economic status was expected.

RESULTS

A total of 59 355 livebirths to residents of Vaud and

TABLE 2 *Per cent distribution of selected risk factors for infant death according to maternal residence. Single livebirths delivered in hospitals, 1979-1985*

	Maternal residence		
	Valais	Vaud	Vaud excl. Lausanne
Sex			
Male	51.6	51.4	51.3
Female	48.4	48.6	48.7
Maternal age (years)			
<20	3.8	2.3	2.3
20-34	89.5	89.6	89.9
≥35	6.7	8.0	7.8
Maternal marital status			
Currently married	95.5	93.5	94.4
Other	4.5	6.5	5.6
Socio-economic group			
Academic, professions	12.8	11.2	12.0
Managerial staff	14.6	22.8	21.2
Skilled workers	56.3	48.0	47.9
Unskilled workers	12.3	11.2	10.2
Agriculture, self employed	2.9	4.6	6.7
No profession/unemployed/ apprentice/etc.	1.2	2.0	1.9
Unknown	0.0	0.0	0.0

Valais were registered over the study period. While Vaud was characterized by a larger population, the numbers of livebirths in Valais and in Vaud were comparable after exclusion of the district of Lausanne (Table 1). The proportion of single livebirths ranged between 97.9% and 98.1%; more than 99.5% of them were delivered in hospitals both in Vaud and in Valais. The proportion of births weighing <2500 g and <2000 g was similar in both regions. Table 2 shows additional characteristics of Valais and Vaud residents. Younger maternal age was more frequent in Valais, an observation balanced by the higher proportion of mothers aged ≥35 in Vaud. There were slightly more married mothers in Valais. The socio-economic structure shows a larger proportion of higher level professions in Vaud and there were more skilled workers in Valais. Among the characteristics available for married mothers only, parity was lower in Vaud (mean 1.6) than in Valais (1.8), due to a higher proportion of first order births in Vaud (49% versus 43% in Valais) and a lower proportion of births of rank 4 and over (1.8% versus 4.2% in Valais).

In contrast to the similar birthweight distributions the crude tertiary NICU use rates varied greatly between Valais (5.7/1000) and Vaud (42.1/1000), with a somewhat lower rate observed in Vaud after exclusion of the district of Lausanne (33.4/1000) (Table 3). When both secondary and tertiary NICU beds were considered, the observed variations in crude use rates were reduced. As a result, the tertiary level of care amounted to 19% of the total NICU use in Valais, compared with 65% in Vaud, and 70% after exclusion of births to residents of Lausanne. Neonatal and infant mortality were low, but Valais experienced a 26% higher rate during the neonatal period and a 21% higher rate than Vaud over the whole first year of life. Neonatal deaths constantly accounted for 55-57% of the infant mortality rate in both areas.

Use of tertiary care was notably higher in Vaud than in Valais. After control of all the variables found to be significantly associated either with neonatal or with infant mortality at a conservative level ($P < 0.1$), the adjusted OR for NICU tertiary bed use reached 13.01 when Vaud was compared to Valais, with a somewhat lower estimate (8.87) after exclusion of Lausanne (Table 4). The OR increased when analyses were repeated for the lowest birthweight subgroups, from a value of 8.15 (6.26 after exclusion of Lausanne) among normal birthweight newborns to 26.32 (19.64 Lausanne excluded) in the <2000 g category.

Using a broader definition covering all beds located in an organized NICU (secondary or tertiary levels), bed use was still significantly higher in Vaud than in Valais, even after exclusion of Lausanne (Table 5). However, the OR for NICU use dropped to 2.55 overall in normal and

TABLE 3 Crude neonatal intensive care unit (NICU) use and mortality rates according to maternal residence at birth, single livebirths delivered in hospitals, 1979-1985

	Valais		Maternal residence Vaud		Vaud excl. Lausanne	
	No.	Rate (/1000)	No.	Rate (/1000)	No.	Rate (/1000)
NICU use						
Tertiary	112	5.66	1609	42.13	863	33.38
Secondary or tertiary	574	29.03	2478	64.89	1229	47.53
Mortality						
Neonatal	111	5.61	170	4.45	113	4.37
Infant	193	9.76	308	8.07	203	7.85

<2500 g birthweight subgroups, although newborns weighing <2000 g were still characterized by a slightly higher OR when Vaud was compared to Valais.

The link between maternal residence and infant mortality was much weaker. Overall, residence in Vaud was associated with a significantly lower neonatal mortality when compared with Valais (Table 6), when Vaud was defined both with and without inclusion of the district of Lausanne. However, the difference in mortality was observed only among newborns weighing ≥ 2500 g, with an estimated OR of 0.74 (0.69 when Vaud was compared to Valais after exclusion of Lausanne). Table 7 shows that the lower mortality persists in Vaud compared to Valais, when limited to the normal birthweight category, for the whole first year of life. The estimated OR were closer to 1.0 for infant mortality, which indicates a reduction in the regional mortality difference during the postneonatal period. The observation of higher infant mortality lim-

ited to the normal birthweight category was reinforced by a lower crude rate for Vaud residents in all 500 g categories above 2500 g, and by similar rates under this birthweight limit. However, the absence of a mortality difference between regions in the low birthweight group might be explained by power considerations; the limited sample size did not permit the study of mortality in subgroups of very low birthweight newborns.

Repeated analyses after restriction of the study population to births to married mothers led to similar estimates both for NICU use and for mortality.

DISCUSSION

Our results show large geographical variations in the use of tertiary NICU beds, particularly among low birthweight newborns. Unexpectedly, the lower use rates observed in Valais were not paralleled by a higher neonatal or infant mortality in the low birthweight group,

TABLE 4 Adjusted^a odds ratio of tertiary neonatal intensive care unit use according to maternal residence at birth, single livebirths delivered in hospitals, 1979-1985

	Maternal residence			
	Vaud compared to Valais		Vaud, excl. Lausanne compared to Valais	
	Odds ratio	95% confidence interval	Odds ratio	95% confidence interval
All birthweights	13.01	10.23-16.54	8.87	7.02-11.20
≥ 2500 g	8.15	6.21-10.70	6.26	4.73-8.28
<2500 g	17.98	12.52-25.81	12.51	8.79-17.80
<2000 g	26.32	16.52-41.93	19.64	12.12-31.80

^aAll birthweights: adjustment for 250 g birthweight category and its square, sex, 250 g birthweight category \times sex, nationality and socio-economic group.

≥ 2500 g: adjustment for 250 g birthweight category, sex, nationality and socio-economic group.

<2500 g: adjustment for 250 g birthweight category, sex and nationality.

<2000 g: adjustment for 250 g birthweight category, sex and socioeconomic group.

TABLE 5 *Adjusted* odds ratio of secondary or tertiary neonatal intensive care unit use according to maternal residence at birth, single livebirths delivered in hospitals, 1979-1985*

	Maternal residence			
	Vaud compared to Valais		Vaud, excl. Lausanne compared to Valais	
	Odds ratio	95% confidence interval	Odds ratio	95% confidence interval
All birthweights	2.55	2.30-2.83	1.77	1.58-1.98
≥2500 g	2.55	2.27-2.88	1.76	1.54-2.01
<2500 g	2.57	2.10-3.15	1.87	1.51-2.31
<2000 g	4.07	2.90-5.72	2.76	1.93-3.94

*See footnote Table 4.

either in general or in any of the repeated analyses performed for <2000 g newborns, for births to married mothers, or after exclusion of the population of Lausanne, the chief town in Vaud. This finding raises the need for additional studies to test this observation and probe more fully than was possible in the current investigation. It contrasts with multiple reports of survival gains obtained in low birthweight groups from the introduction of neonatal intensive care,²⁶ from evaluation research devoted to the regionalization of perinatal care,¹⁶⁻¹⁸ from data published by NICU²⁷⁻³⁰ and from population-based studies.³¹⁻³⁵ However, a dose-response relationship between the level of neonatal intensive care and the survival of low birthweight newborns has been reported only among newborns weighing <1500 g by Powell and Pharoah.³⁶ While the adjusted OR for infant mortality was 1.0 among <2500 g newborns in our study, our limited sample size precluded the analysis of very low birthweight newborns.

The level of use of tertiary NICU beds in Vaud (4.2%) is not unusual; it remains within the 3-5% of the general population of livebirths observed in other European countries³⁷ and within the 4-6% estimate of tertiary centre use in the US.³⁸ The use of tertiary centres in Valais is well below this range (0.6%).

With time, specialized care is likely to diffuse from tertiary, university affiliated centres to the community. Smaller hospitals may create NICU, and paediatricians working in maternity services are often trained in neonatal intensive care. Special beds devoted to the neonatal care of frail newborns with moderately reinforced equipment and staffing can be considered as secondary NICU. The diffusion of neonatal intensive care from teaching centres to smaller hospitals might be an explanation of the low neonatal and infant mortality rates generally observed in Valais, and of the similarity of infant mortality among low birthweight newborns in Vaud and Valais. Our results demonstrated a clear reduction in regional variation of NICU use when both secondary and tertiary levels were considered. The unit located in a regional hospital in Valais did not provide a whole range of neonatal services and was not permanently staffed as a tertiary NICU, but it offered intensive care such as mechanical ventilation and contributed locally to newborn care as an unofficial referral centre. In addition, many of the physicians in charge of paediatric wards in Valais hospitals were trained in NICU, and might have applied their specialized knowledge outside the structured units specifically devoted to neonatal intensive care.

TABLE 6 *Adjusted* odds ratio of neonatal mortality according to maternal residence at birth, single livebirths delivered in hospitals, 1979-1985*

	Maternal residence			
	Vaud compared to Valais		Vaud, excl. Lausanne compared to Valais	
	Odds ratio	95% confidence interval	Odds ratio	95% confidence interval
All birthweights	0.74	0.57-0.97	0.69	0.52-0.93
≥2500 g	0.63	0.44-0.91	0.52	0.34-0.79
<2500 g	0.85	0.58-1.25	0.90	0.60-1.35
<2000 g	0.91	0.57-1.47	0.98	0.59-1.63

*See footnote Table 4.

TABLE 7 Adjusted^a odds ratio of infant mortality according to maternal residence at birth, single livebirths delivered in hospitals, 1979–1985

	Maternal residence			
	Vaud compared to Valais		Vaud, excl. Lausanne compared to Valais	
	Odds ratio	95% confidence interval	Odds ratio	95% confidence interval
All birthweights	0.82	0.68–0.99	0.79	0.64–0.97
≥2500 g	0.74	0.59–0.93	0.69	0.53–0.89
<2500 g	1.00	0.71–1.43	1.03	0.71–1.49
<2000 g	1.07	0.67–1.71	1.08	0.66–1.79

^a See footnote Table 4.

Nevertheless, evaluations of regionalization programmes have shown declines not only in mortality but also in selected morbidity with increased proportions of low birthweight newborns being admitted to tertiary centres.³⁹ The open question behind similar mortality rates in regions characterized by large variations in tertiary neonatal care use remains the quality of life for low birthweight newborns surviving to their first year of life.

Normal birthweight newborns, also characterized by a higher level of tertiary NICU use in Vaud, experienced a significantly higher mortality when maternal residence was in Valais rather than in Vaud. The regional difference was larger for neonatal than for infant mortality, indicating a low probability of an effect of the socio-economic environment. Considering the similarity of the birthweight distribution in Vaud and Valais, major regional differences in antenatal care leading to a differential in neonatal mortality are not likely. Although information regarding malformations was not available, regional differences in the rate of birth defects would also affect birthweight distribution. The low numbers of observed deaths limited this aspect of the research. The second limitation, specific to newborns weighing ≥ 2500 g, is the lower potential of variables such as birthweight (considered as a powerful determinant of mortality among newborns weighing < 2500 g) for the control of possible population differences in the normal birthweight range; this limitation is associated with linked birth and death certificates as the data source. Nevertheless, the pattern of mortality differences between Vaud and Valais among normal birthweight newborns suggests the influence of events occurring at birth or early in the first year of life. The risk identification process, in a region characterized by limited specialized resources and a low referral rate to tertiary NICU, remains a possible explanation for our results. Low-risk deliveries in primary hospitals are frequently performed by medical residents during their training years; poor detection of those at risk among normal

birthweight newborns associated with the low referral rates generally observed in Valais might result in the higher mortality observed for this region.

Replication of such research in larger areas and the monitoring of birth defects in the population appear to be priorities following the observation of marked variations in the use of neonatal intensive care.

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