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Cost-Minimization Analysis of Domiciliary Antenatal Fetal Monitoring in High-Risk Pregnancies

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Objective: **To compare safety and cost-effectiveness of domiciliary antenatal fetal monitoring (cardiotocography and obstetric surveillance) with in-hospital monitoring in high-risk pregnancies.**

Methods: **From September 1992 to June 1994, 150 consecutive women with high-risk pregnancies, who would otherwise be monitored in the hospital, entered a randomized controlled trial of in-hospital ($n = 74$) or domiciliary ($n = 76$) monitoring. The main outcome measures were neonatal safety (Prechtl neurologic optimality score, the proportion of non-optimals) and cost-effectiveness. To test a two-point difference in mean Prechtl scores (two-tailed $\alpha = .05$, $1\text{-}\beta = .80$), 150 women were needed. Safety and cost-effectiveness were analyzed according to intention to treat. Conditional on the safety outcomes, a cost-minimization analysis based on actual resource use was performed. Uncertainty of results was explored by sensitivity analyses.**

Results: **Neonatal outcomes were equal. No cost-shifting between the antenatal and postpartum period occurred. Substituting domiciliary for in-hospital monitoring reduced mean (standard deviation) antenatal costs from $3558 ($2841) to $1521 ($1459) per woman ($P < .001$). If costs were varied by the addition of 50%, costs were still reduced. The magnitude of the reduction was sensitive to the costs of hospital care and less sensitive to the costs of domiciliary monitoring.**

Conclusion: **Domiciliary monitoring is safe and reduces costs by one-half. The technique seems transferable to other settings but local circumstances may sometimes hamper its dissemination. (Obstet Gynecol 1997;89:925–9. © 1997 by The American College of Obstetricians and Gynecologists.)**

Prenatal care aims at the prevention, early detection, and possible treatment of obstetric complications. Prenatal care in the Netherlands is stratified.[1,2] If the pregnancy is low risk and proceeds well, primary-care midwives are responsible for full obstetric care and the delivery. Women with pregnancies considered high obstetric risks are hospitalized antenatally (17.7%) or in labor (20.1%)[3] for clinical surveillance and delivery by obstetricians. The effectiveness of stratified care depends on well-trained midwives and unequivocal criteria to identify high-risk pregnancies. The official *Index of Medical and Obstetric Risks*[4,5] defines which conditions are considered high risk.

The invariable hospitalization of high-risk women has been criticized. Frequently, clinical surveillance and care in high-risk women are limited. Domiciliary antenatal fetal monitoring, particularly in a medium-care subgroup, has been shown to be a feasible alternative to in-hospital monitoring.[6,7] Potential benefits of domiciliary monitoring include avoided hospitalization and dissatisfaction with inpatient stay, reduced maternal stress, and no disrupted family life.[8,9] Alongside a randomized controlled trial, we investigated the clinical safety and cost-effectiveness of a domiciliary antenatal fetal-monitoring program compared to conventional in-hospital monitoring in selected high-risk pregnancies. If domiciliary monitoring proved safe and efficient compared to in-hospital monitoring, opportunities would emerge to tailor the use of high-cost clinical obstetric care.

Materials and Methods

The study population included women referred to the antenatal clinic who lived near the hospital and had one (or more) of 15 predefined high-risk conditions listed in the *Index of Medical and Obstetric Risks*. Subjects were excluded if they did not have suitable housing or did not give informed consent.

Women were assigned randomly 1:1 to domiciliary or

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in-hospital monitoring (unstressed antenatal fetal heart rate and uterine activity monitoring [cardiotocography] and obstetric surveillance). Randomization was executed by a software supported block-randomization scheme stratified for gestational age (under 37, 37–42, and 42 or more weeks) with random permuted blocks within strata. The trial was approved by the hospital's Medical Ethics Committee.

Women allocated to in-hospital monitoring were hospitalized and monitored daily. If necessary, they received additional diagnostics or treatment. Women allocated to domiciliary monitoring went home with a checklist of conditions that required immediate hospitalization. A midwife visited each woman daily for antenatal monitoring (portable cardiotocography; Oxford Sonicaid System 8000, Oxford Instruments Inc., Gorinchem, The Netherlands) and transmitted the tracings by public telephone network to the hospital. Domiciliary monitored women were seen weekly at the antenatal clinic.

An obstetrician responsible for the treatment of the domiciliary-monitored women assessed the monitoring tracings. Women no longer at high risk were discharged from the hospital or from domiciliary monitoring. All high-risk women should deliver in the hospital. If the discharge of either mother or neonate was delayed, then both were hospitalized.

Cost-effectiveness analysis was used as the primary evaluation framework.[10] Economic outcome was defined initially as the cost difference between the strategies per averted non-optimal neonate. Primary neonatal outcomes were Prechtl neurologic optimality score[11] (a proxy for the neonate's future health state)[12,13] and the proportion of non-optimal neonates (Prechtl score no more than 57). Secondary outcomes were gestational age at delivery, birth weight, Apgar scores at 1 and 5 minutes, and the proportion of reanimated or artificially ventilated neonates.

A two-point difference in mean Prechtl scores was considered clinically relevant.[12] To test (two-tailed α = .05, 1-β = .80) a two-point difference in mean (standard deviation [SD] 4.3) Prechtl scores, 150 women were needed. If the neonatal outcomes were equal, then clinical safety was established and economic outcome equalled the cost difference between the strategies (cost-minimization analysis).[10] Cost differences could occur antenatally, during delivery, and postpartum. Cost-shifting was defined as when an antenatal cost advantage was offset by a cost disadvantage at a later stage. Antenatal costs were calculated as actual resource use multiplied by the costs per resource unit using 1993 prices. The costs per resource unit of hospital-based care and domiciliary monitoring included fixed and indirect costs. The costs of in-hospital nursing care were not corrected for variations in nursing intensity. Other volumes were valued using data from the trial or Dutch reference data.[14] Costs were converted into U.S. dollars (1993 purchasing power parity: DFL 1.00 = US $0.47).[15]

All outcomes were analyzed according to intention to treat. The neonatal outcomes were compared to establish safety. Conditional on that outcome, we verified the absence of cost-shifting. Next, we reported the resource use of each strategy and the cost difference between the strategies. Uncertainty of results was explored by sensitivity analyses.

Proportions and categoric data were compared with χ^2 and Yates correction. Length of stay and cost data were compared with the Mann-Whitney U test. $P < .05$ (two-tailed) was considered significant.

Results

From September 1992 to June 1994, 174 consecutive high-risk women met the inclusion criteria. Twenty-four women were excluded, including one woman who was excluded retroactively because of proven hard-drug use. Eligible women were allocated to domiciliary monitoring (n = 76) or in-hospital monitoring (n = 74). There were no significant differences between the two groups (Table 1). Neonatal mortality and the primary and secondary outcomes were equal between the groups (Table 2). Consequently, domiciliary monitoring was regarded as a safe substitute for in-hospital monitoring. Equal outcomes allowed for a cost-minimization framework.

To investigate potential cost-shifting, we checked the length of antenatal and postpartum stay and the mode of delivery (Table 3). All women but one delivered in the hospital. The proportion of induced deliveries and the mode of delivery were not significantly different. In the in-hospital monitoring group, significantly more women were hospitalized after the delivery (Table 3). The length of the maternal and neonatal postpartum stay did not differ significantly. In the domiciliary monitoring group, neonates were hospitalized at the maternity ward for a significantly shorter time. This cost advantage was offset by a cost disadvantage at the pediatric and neonatal wards. The mean (SD) postpartum costs were $3433 ($4273) for the in-hospital group and $3480 ($5895) for the domiciliary group. The postpartum costs did not differ significantly (P = .155). Hence, cost-shifting did not occur.

The median length of the antenatal period was equal between the groups. The length of the antenatal period did not differ significantly (Table 3). The in-hospital monitoring group spent on average 9.3 days in the hospital and 2.9 days at home. Women in the domicil-

Table 1. Baseline Characteristics

	Allocated monitoring strategy		
	In-hospital (n = 74)	Domiciliary (n = 76)	No consent (n = 23)
Maternal age at study entry*			
≤24 y	10	17	9
25–34 y	50	41	12
≥35 y	14	18	1
Married, living together	81%	84%	100%
White mother	53%	46%	39%
Educational level			
Primary school	7	3	2
High school	52	62	15
College or university	15	11	6
Paid job	72%	68%	41%
Nullipara	55%	55%	65%
Gestational age at study entry			
≤37 wk	30	32	10
38–41 wk	29	27	6
≥42 wk	15	17	7
High-risk indications†			
Post-date, uncomplicated	17 (0)	17 (0)	7 (0)
Diabetes	17 (1)	20 (2)	4 (0)
Mild hypertension	20 (5)	19 (10)	7 (1)
Fetal growth restriction	18 (2)	17 (2)	3 (0)
Other‡	2 (0)	3 (0)	2 (0)

* The age of one woman in no consent group was unknown.
† The number of women with a second high-risk indication is given parenthetically.
‡ Non-progressive cervical dilation (n = 1), premature rupture of membranes (n = 2), twin gestation (n = 3), or previous intrauterine fetal death (n = 1).

iary monitoring group spent on average 1.9 days in the hospital and 9.3 days at home. The length of antenatal stay in the hospital and at home differed significantly between the groups (Table 3). Four women in the

Table 2. Neonatal Outcome

	Allocated monitoring strategy	
	In-hospital (n = 74)	Domiciliary (n = 76)
Birth weight (range)	1190–4770 g	970–5180 g
Gestational age at delivery (mean [SD])	40.4 (2.5) wk	39.9 (2.5) wk
Perinatal mortality	1	1
Neurologic optimality* (mean [SD])	57.7 (2.7)	58.1 (2.4)
Non-optimals†	32%	29%
1-minute Apgar scores (median [range])	9 (2–10)	9 (4–10)
5-minute Apgar scores (median [range])	10 (6–10)	10 (7–10)
Reanimation or ventilation	11%	18%

SD = standard deviation.
* Prechtl neurologic optimality score at 6–8 days postpartum. Range 0–60, a higher score indicates a better neurologic condition.
† Defined as Prechtl score ≤57.

Table 3. Treatment Setting

	Allocated monitoring strategy		
	In-hospital (n = 74)	Domiciliary (n = 76)	P
Antenatal period (d)			
In observation*	8.0 (3–18)	8.0 (4–17)	.909
In-hospital	7.0 (3–12)	1.0 (0–1)	< .001
At home	0.0 (0–0)	6.5 (3–13.8)	< .001
Delivery			
Induction	36.5%	30.3%	.525
Mode of delivery			
Vaginal spontaneous	52	55	
Instrumental	7	6	
Primary cesarean	8	5	
Secondary cesarean	7	10	.716
Postpartum period (d)			
Hospitalized after delivery†	93.2%‡	61.8%	< .001
Mother	4.0 (2–7)	3.0 (0–7)	.121
Neonate	4.0 (2–7)	3.0 (0–7.8)	.231
Maternity ward	2.0 (1–5)	0.0 (0–4)	.013
Pediatric ward	0.0 (0–1)	0.0 (0–1)	.929

Data are presented as median (inter-quartile range) days or n.
* The number of days between the first monitoring session and the onset of the delivery.
† Not discharged within 24 hours postpartum.
‡ Proportion based on 74 women, including one woman who unexpectedly delivered at home.

in-hospital monitoring group delivered before initial hospitalization. Fourteen women no longer at high risk were discharged antenatally and re-hospitalized at the onset of the delivery. In the domiciliary monitoring group, three women delivered before the initial monitoring session, and 49 women were hospitalized at the onset of the delivery. The remaining 24 women were hospitalized antenatally (16 for suspect cardiotocography recordings, one for raised tension, one for an abnormal laboratory test, one for suspected infection, and five for other reasons), of whom seven were also discharged antenatally.

The location of antenatal stay determined antenatal resource use and costs (Table 4). In the in-hospital monitoring group, costs were $14,280 or less. Of the total costs, 94% were covered by in-hospital nursing care (84%) and informal family care (10%). In the domiciliary monitoring group, costs were $9266 or less. Of the total costs, 83% were covered by nursing care (40%), domiciliary monitoring (28%), and informal family care (15%). The mean (SD) total costs, $3558 ($2841) in the in-hospital monitoring group and $1521 ($1459) in the domiciliary monitoring group, resulted in a $2037 cost difference. The total costs differed significantly between the groups ($P < .001$).

If all women allocated to in-hospital monitoring were to stay in the hospital, and if all domiciliary monitored

Table 4. Antenatal Resource Use

Cost item*	In-hospital (n = 74) mean use†	Domiciliary (n = 76) mean use†	Costs per unit in US $
Direct medical costs			
In-hospital costs			
Nursing care (d)	9.26 (70)	1.86 (24)	323.94
Monitoring sessions	9.22 (70)	1.86 (24)	7.51
Ultrasonography	0.64 (37)	0.21 (15)	37.56
Laboratory tests	1.11 (38)	0.25 (12)	7.89
Medication (d)	1.89 (10)	0.34 (9)	0.88
Dietary measures (d)	4.50 (27)	0.99 (39)	0.33
Out-of-hospital costs			
Visits (outpatient)	0.28 (10)	1.04 (46)	40.85
Monitoring sessions (outpatient)	0 (0)	1.01 (46)	43.66
Ultrasonography (outpatient)	0.01 (1)	0.46 (26)	53.05
Laboratory test (outpatient)	0.03 (1)	0.33 (16)	7.89
Monitoring sessions (home)	0 (0)	7.79 (73)	54.93
Medication (home)	0 (0)	1.90 (9)	0.91
Primary care (home)	0 (0)	0 (0)	n.a.
Direct non-medical costs			
Dietary measures (d)	0 (0)	5.22 (39)	0.33
Traveling expenses woman (km)	10.26 (74)	19.39 (76)	0.18
Professional home help (h)	0 (0)	2.54 (13)	18.78
Traveling hospital visits (km)	113.28 (73)	21.76 (56)	0.18
Indirect costs			
Informal family care (h)‡	18.53 (na)	11.77 (na)	18.78
Premature pregnancy leave (h)	8.88 (8)	9.20 (7)	8.05

na = not applicable.

Data are presented as mean antenatal resource use (intention-to-treat analysis).

* Cost items are measured in physical units, number of days (d), hours (h), or kilometers (km).

† For every cost item, the number of women with non-zero resource use is given in parentheses.

‡ This cost item shows the increase in informal family care attributable to high risk.

women were to stay at home until the onset of the delivery, then the cost difference would amount to $3378 per woman. In routine obstetric care, women no longer at high risk are discharged, and women may be hospitalized for clinical or social reasons. This reduces the cost difference from $3378 to $1787 per woman in our study (adjusted for a minor imbalance in the number of days in antenatal observation). Sensitivity analyses showed that the $1787 cost difference was particularly sensitive for changes that affected the costs of hospital-based nursing care and the costs of domiciliary monitoring sessions. For example, a 50% reduction in the costs of hospital nursing care reduced the cost difference by 62%. A 50% reduction in the costs of domiciliary monitoring sessions increased the cost difference by 13%. If the annual high-risk incidence of 94.4 women could be sustained in routine obstetric care, the costs would be reduced by approximately $168,700 (94.4 × $1787) annually.

Discussion

Domiciliary monitoring by portable cardiotocography and trained midwives proved clinically safe and feasible, irrespective of maternal ethnicity, educational level, or family support. The antenatal costs were substantially reduced, mainly through avoided hospitalization, without evidence of cost-shifting. Hence, domiciliary monitoring may release hospital resources to be reallocated more efficiently to the benefit of other patients.

Volunteer bias is unlikely to have influenced our results. Withdrawal after randomization and losses to follow-up did not occur. Prechtl neurologic examination was unblinded, but an interobserver study did not reveal significant differences. We found no evidence that the domiciliary monitoring group was more compliant or healthy than the in-hospital monitoring group. Hence, significantly different neonatal outcomes seem unlikely. The mode of delivery was equal, suggesting that maternal short-term quality of life would not differ. Hospital admission and discharge were under human control. Although the incentive to discharge was similar in both groups and patients were not labeled, the length of hospitalization, and thereby the cost difference, may be biased.

External validity depends on the transferability of domiciliary monitoring to other settings. Applying these results in Dutch obstetric care to other settings will depend mainly on the high-risk indications, professional acceptance, and women's access to the hospital. In the United States[16] and France,[17] domiciliary monitoring is used mainly to monitor uterine activity as a preventive measure to reduce the incidence of preterm labor and birth. The high-risk indications agree partially with ours.[18] The high-risk indications we used correspond more closely to those applied in the United Kingdom.[7] Our high-risk indications may be refined and even extended. Risks that do not justify in-hospital monitoring should not be included.

Dutch obstetricians hold a "naturalistic" view on the nature of pregnancy and labor.[1,19] Professionals who do not share this view may hesitate to accept domiciliary monitoring in principle or because of legal or financial motives.[20] Moreover, as bed occupancy rates and inpatient days are common budget variables, professionals may perceive the budget consequences as undesirable. Furthermore, the obstetric case mix may shift toward more severe patients.

After domiciliary monitoring is implemented in routine care, hospital care must remain accessible and available when fetal or maternal health, the delivery, or

nonclinical reasons justify hospitalization. Moreover, some women might prefer hospitalization because of its perceived safety and convenience. A partial budget reallocation may be combined with financial or other incentives for patients and providers to promote efficient behavior. Domiciliary monitoring offers a clinically sound alternative for the currently proposed reimbursement limits on the inpatient stay of obstetric patients.[21,22]

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