JOGNN IN REVIEW

The Circadian Rhythm of Blood Pressure During Pregnancy

Cheryl D. Larry, RN, CNM, CNS, SeonAe Yeo, RN, PhD

Objective: To review the literature on the circadian rhythm of blood pressure during pregnancy.

Data Sources: Computerized searches on MEDLINE, CINAHL, and MIRLYN.

Study Selection: Selected studies from 1969 to 1997 were evaluated.

Data Extraction: Data were extracted and information was organized under the following areas: definition of and the interconnection between circadian rhythm and blood pressure; the circadian variability of blood pressure throughout the trimesters; the patterns of the circadian rhythm of blood pressure in pregnancies defined as normal and those complicated by chronic hypertension and preeclampsia; and clinical implications.

Data Synthesis: The circadian rhythm of blood pressure in pregnancy is the same as in the nonpregnant state, with a nocturnal decrease, especially during sleep. In patients with chronic hypertension, the nocturnal fall in blood pressure may be steeper. Patients with mild preeclampsia may experience a less pronounced nocturnal decrease in blood pressure. Patients with severe preeclampsia may display a reversed circadian rhythm, with no decrease and/or an increase in nocturnal blood pressure.

Conclusions: The patterns of the circadian rhythm of blood pressure during normal pregnancy and pregnancies complicated by chronic hypertension and preeclampsia warrant consideration when monitoring patients and implementing management plans. *JOGNN, 29*, 500–508; 2000.

Keywords: Blood pressure—Chronic hypertension—Circadian rhythm—Preeclampsia—Pregnancy—Suprachiasmatic nuclei

Accepted: November 1999

Continuous monitoring of blood pressure throughout the day and night reveals that blood pressure values form a characteristic circadian pattern. In women with normal pregnancies, significant decreases in systolic and diastolic pressures are noted at night, with minimum values typically occurring between midnight and 4:00 a.m. The pressures increase during the waking hours, reaching a maximum by late evening (Delea, 1979; Sawyer, Lipshitz, Anderson, Dilts, & Halperin, 1981; Weber, Drayer, Nakamura, & Wyle, 1984).

A circadian rhythm is the regular recurrence of any phenomenon that retains a periodicity or rhythmicity of approximately 24 hours under constant conditions (Clancy & McVicar, 1994; Honnebier & Nathanielsz, 1994; Miller & Keane, 1987). Many biologic phenomena, such as body temperature, endocrine function, and uterine activity, demonstrate circadian rhythmicity (Smeltzer & Bare, 1992).

The genesis of circadian rhythm is endogenous and exists as a physiologic system measuring time, a biologic clock (Dunlap et al., 1995). Thus, the rhythms persist in the absence of environmental time cues (Minors & Waterhouse, 1981; Moore-Ede, Sulzman, & Fuller, 1982). The human circadian rhythm has a free-running period of about 25 hours, which is subsequently entrained or modified via environmental cues to fit within the 24-hour solar day (Arendt, Minors, & Waterhouse, 1989; Clancy & McVicar, 1994; Minors & Waterhouse, 1981; Moore-Ede et al., 1982; Seron-Ferre, Ducsay, & Valenzuela, 1993). In 1954, Aschoff coined the term *zietgeber*, which means time-giver, to denote the environmental signals that provide cues to synchronize the circadian rhythm (Binkley, 1990; Seron-Ferre et al., 1993; Tolstoi, 1994). Social cues and the light-dark cycle influence circadian rhythms in humans.

The suprachiasmatic nuclei (SCN) of the hypothalamus serves as the pacemaker for circadian rhythms, where signals from the environment are integrated to adjust the rhythm to approximately 24 hours (Clancy & McVicar, 1994; Efinger, Nelson, & Walsh-Starr, 1995; Gillette et al., 1995; Ralph & Hurd, 1995; Seron-Ferre et al., 1993). A specialized retinohypothalamic tract links the retina to these nuclei, thus forming a nonvisual photoreceptic system that synchronizes the circadian pacemaker with the light-dark cycle in the environment (Czeisler et al., 1990). Timing information is then conveyed to the rest of the organism, and the result is a circadian rhythm composed of exogenous and endogenous components.

Blood Pressure

Like other physiologic phenomena, blood flow possesses rhythmicity. This rhythmicity is measured by heart beats for frequency and by blood pressure for intensity. Blood pressure and heart beat are two of the physiologic parameters most commonly measured by nurses. Blood pressure is defined as the pressure of the blood against the walls of the blood vessels during one complete beat of the heart (Miller & Keane, 1987). Blood pressure is affected by cardiac output; dilatation of the arteries; and the volume, velocity, and viscosity of the blood (Smeltzer & Bare, 1992). Individual demographic variables such as age, gender, race, socioeconomic status, occupation, and education also influence blood pressure (Thomas & Dekeyser, 1996).

Blood pressure is expressed as the systolic pressure (the peak pressure occurring when the ventricles of the heart contract) over the diastolic pressure (the lowest pressure occurring when the ventricles of the heart are resting) (Miller & Keane, 1987). The normal adult values range from 100/60 mm Hg to 140/90 mm Hg, with an average normal blood pressure of 120/80 mm Hg (Miller & Keane, 1987; Smeltzer & Bare, 1992). The mean arterial pressure (MAP) expresses the pressure driving blood into the tissues averaged over the entire cardiac cycle and is defined as (systolic blood pressure + diastolic blood pressure x 2)/ 3. Blood pressure readings can be obtained by indirect (noninvasive use of a sphygmomanometer and stethoscope) and direct (insertion of an arterial catheter into an artery) methods of measurement. Direct methods are more accurate and less subject to error, but are invasive and require strict monitoring of the patient.

Ambulatory blood pressure monitoring is an indirect measure which allows continuous monitoring in a nonclinical environment. This method is gaining acceptance as a tool for early diagnosis of hypertension and cardiac conditions (Perloff, Sokolow, & Cowan, 1983). The data produced from this method portray the actual circadian pattern of blood pressure (Weber et al., 1984). Ambulatory recordings enable the clinician to take into account the variability of blood pressure throughout a 24-hour period and distinguish between patients with a "white coat syndrome" of elevated pressures and those with true hypertension (Ferguson, Neubauer, & Sharr, 1994).

Twenty-four hour monitoring provides multiple data points to portray the circadian pattern of blood pressure in the pregnant woman.

Circadian Rhythm of Blood Pressure

While it is recognized that blood pressure is affected by a circadian rhythm, the effects of this rhythm have not been well explored in nursing risk assessment or research. According to Seligman (1971) and Delea (1979), studies on the variability of blood pressure began at the end of the 1800s. By 1898, with the use of the newly designed sphygmomanometer, researchers found that blood pressure changed depending on whether the subject was sleeping, resting, or working.

Blood pressure fluctuates throughout the day and night. The duration of the fluctuations may be short, from seconds to minutes; or long, from day to night and season to season (Weber et al., 1984). The most easily noted and significant blood pressure variations are the diurnal changes related to the sleep-wake cycle (Coca, 1994; Weber et al., 1984). The pattern of blood pressure values obtained during the sleep-wake cycle form a characteristic circadian rhythm. Continuous monitoring of blood pressure throughout the day and night reveals a pattern with minimum values of systolic and diastolic pressures between midnight and 4:00 a.m. The pressures increase during the waking hours, remaining at a plateau for several hours and then reaching a maximum value by late evening. Blood pressure returns to its minimum values early in the morning (Delea, 1979; Minors & Waterhouse, 1981; Sawyer et al., 1981; Weber et al., 1984). This diurnal blood pressure fluctuation is altered in certain disease states, such as preeclampsia and chronic hypertension (Baumgart, 1991).

Circadian Blood Pressure Variation Throughout Pregnancy

Maternal cardiovascular adaptation to pregnancy involves sizable change throughout the trimesters. Pregnancy relaxes peripheral vascular resistance, in part because of increased progesterone, a smooth muscle relaxant (Blackburn & Loper, 1992; Cruikshank, Wigton, & Hays, 1996). This reduction in vascular resistance results in a fall of systemic arterial blood pressure.

In healthy pregnant women, the systolic and diastolic blood pressures begin to fall during the 1st trimester, continuing to decrease until midpregnancy (an average of 5 to 10 mm Hg for systolic and 10 to 15 mm Hg for diastolic pressure) and then gradually return to nonpregnant baseline levels by the end of the 9th month (Ayala, Hermida, Cornelissen, Brockway, & Halberg, 1994; Ayala, Hermida, Mojon, Fernandez, & Iglesias, 1997; Ferguson et al., 1994; Gallery, Hunyor, Ross, & Gyory, 1977; MacGillivray, Rose, & Rowe, 1969).

In 1993, Contard et al. used an ambulatory monitoring device to study blood pressure in women with normal pregnancies. The circadian variation of arterial pressure during each trimester of pregnancy was observed. Forty-eight women were included in the study (19 nulliparae and 29 multiparae), and blood pressure measurements were obtained at 3, 6, and 9 months of gestation. Although a mid-pregnancy value was not obtained, the researchers found that during a normal pregnancy, 24-hour recordings display a pattern with the lowest blood pressure noted during the 1st trimester, a minimal increase noted during the 2nd trimester, and an incremental rise during the last trimester. Blood pressures were found to rise during the day and fall at night for each trimester of pregnancy. A mean nighttime decrease in arterial pressure averaging 15% was noted in all participants during each trimester. In addition, a decrease in systolic blood pressure of at least 10% was noted in all participants during each trimester.

Preeclampsia appears to interfere with the normal decrease in blood pressure at night, sometimes resulting in no decrease or even an increase.

It is generally abnormal for a woman's blood pressure to increase during pregnancy. In women with chronic hypertension, failure of the blood pressure to decrease during the first two trimesters is an unfavorable prognostic sign (Consensus Report, 1990). In women with preeclampsia or gestational hypertension, blood pressure increases throughout the second half of pregnancy (Hermida et al., 1997). Furthermore, preeclampsia appears to interfere with the expected decrease in blood pressure at night, sometimes resulting in no decrease or an increase.

Circadian Rhythm of Blood Pressure During Pregnancy

Seligman (1971) used an automatic cuff-type recorder to study diurnal blood pressure variations in pregnant women. Thirty pregnant women were included in the study: 10 normotensive, 10 with chronic hypertension, and 10 with preeclampsia. Data were collected in the hospital for all participants. Although gestational ages and precise values for each participant in the Seligman study were not cited, four illustrations of 24-hour blood pressure recordings were included: a normal pregnancy at 32 weeks (see Figure 1); severe chronic hypertension at 31 weeks (see Figure 2); preeclampsia at 32 weeks (see Figure 3), and severe preeclampsia at 35 weeks (see Figure 4). Nighttime sedation was omitted or given as nitrazepam, which has no effect on blood pressure. Seligman found that (a) in normal pregnancy, blood pressure falls during sleep as it does for nonpregnant women; (b) a similar pattern exists in pregnant women with chronic hypertension, although the blood pressure fall during sleep is greater than in normotensive women; and (c) in women with preeclampsia, the degree of the fall in blood pressure during sleep is reduced. Seligman found that the nocturnal decrease in blood pressure as a percentage of the highest systolic reading was 30% in the women with preeclampsia compared with 55% in women with chronic hypertension and 50% in normotensive women.

Redman, Beilin, and Bonnar (1976) used an ultrasound device that detected arterial wall movements and provided automatic 24-hour blood pressure readings. Participants were 9 normotensive women and 9 women with untreated chronic hypertension who were observed at 28 and 36 weeks gestation, as well as 17 women with severe preeclampsia (hypertension with either proteinuria or renal impairment) observed at various times during pregnancy. Some of the participants with severe preeclampsia received antihypertensive medications. The findings confirmed that blood pressure reaches the lowest point at night in normotensive and hypertensive women. The mean nocturnal fall for the diastolic pressures of normotensive and chronic hypertensive women at 28 weeks of gestation were similar (-4.8 mm Hg and -6.0 mm Hg, respectively). The systolic blood pressure profiles of the women with

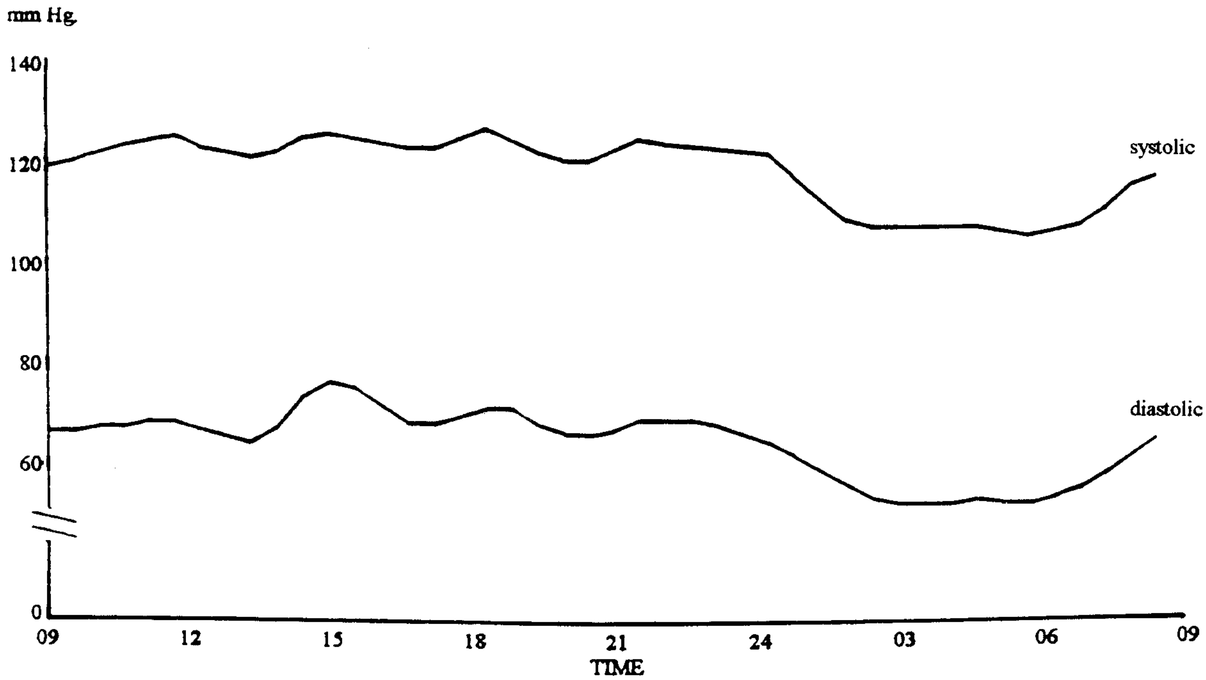

FIGURE 1
Twenty-four hour smoothed record of blood pressure during normal pregnancy at 32 weeks gestation. From "Diurnal Blood-Pressure Variation in Pregnancy," by S. A. Seligman. 1971, *Journal of Obstetrics and Gynaecology of the British Commonwealth, 78,* p. 418. Reprinted with permission.

chronic hypertension, however, revealed a significantly greater fall, -16.3 mm Hg compared with -11.7 mm Hg in the normotensive women. Ten of the seventeen women with severe preeclampsia showed a reversal of the normal diurnal blood pressure pattern, with the highest systolic and diastolic pressures recorded at night. This reversed circadian rhythm was found to be independent of antihypertensive drug administration. All three groups were confined to bed except to use the toilet. Although location was not documented in the Redman et al. study, it seems reasonable to infer that the measurements were made in the hospital.

In 1980, Murnaghan, Mitchell, and Ruff used radial cannulation to obtain continuous direct arterial blood pressure recordings in pregnant women. The participants consisted of 16 normotensive women, 15 untreated chronic hypertensive women, 24 chronic hypertensive women receiving antihypertensive medication, and 8 women with severe preeclampsia and proteinuria. In the women with preeclampsia, the nocturnal blood pressure fall was markedly smaller than in the normotensive and chronically hypertensive women, despite adequate nighttime sedation resulting in uninterrupted sleep. No clear circadian pattern was found in the preeclamptic group. In contrast to Seligman's findings, the normotensive and chronic hypertensive gravidae showed a comparatively similar blood pressure pattern.

Sawyer et al. (1981) used the DINAMAP (device for indirect noninvasive automatic mean arterial pressure) apparatus to compile 24-hour blood pressure profiles for the mean arterial, systolic, and diastolic pressures. Three groups of 15 women in their 3rd trimester were studied: normotensive, chronically hypertensive, and those with mild preeclampsia (blood pressure at or above 160/110 with proteinuria and/or edema). Nine of the women with chronic hypertension had been placed on antihypertensive medications prior to the study, but were admitted to the hospital for uncontrolled blood pressure and thus included in the study. None of the women with mild preeclampsia received antihypertensive medication during the study. The results of the Sawyer et al. study confirm Seligman's (1971) findings and are similar to other reports. Compared with the systolic blood pressure fall in normotensive women, the fall in the women with chronic hypertension was significantly greater during sleep and significantly less in women with mild preeclampsia. Although the diastolic pressure fell during the night as well, no significant difference was found among the three groups. The circadian rhythm was abolished in the two participants with severe preeclampsia. These women experienced no decrease or increase in blood pressure during sleep.

Halligan, Shennan, Lambert, deSwiet, and Taylor (1996) used the Spacelabs 90207 (Spacelabs, Redmond,

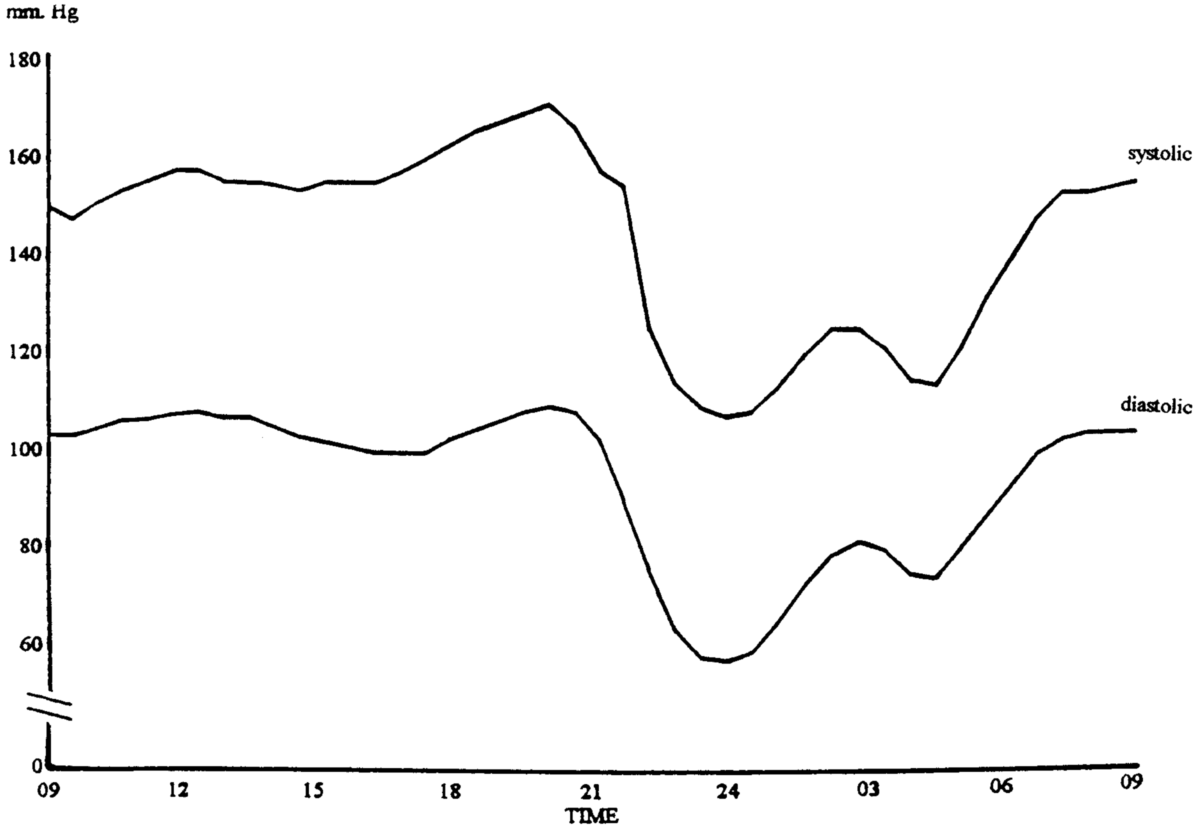

FIGURE 2
Twenty-four-hour smoothed record of blood pressure in a case of severe chronic hypertension at 31 weeks gestation. From "Diurnal Blood-Pressure Variation in Pregnancy," by S. A. Seligman. 1971, *Journal of Obstetrics and Gynaecology of the British Commonwealth, 78,* p. 419. Reprinted with permission.

WA) ambulatory blood pressure monitor to evaluate the diurnal blood pressure variation in women with normal pregnancies and those complicated by preeclampsia. Twenty-four normotensive women and 24 women with untreated preeclampsia were studied at a mean gestational age of 35 weeks. The observations confirmed the findings of previous work describing the diurnal variation of blood pressure. Halligan et al. (1996) found that in normal pregnancy there was a fall in blood pressure, especially during sleep. In the women with preeclampsia, the mean blood pressure was higher than in the normotensive women, thus the phenomenon of nocturnal hypertension also was confirmed. The mean day-night difference for diastolic blood pressure was found to be greater for normotensive women (17.2 mm Hg) than for women with preeclampsia (9.0 mm Hg). The mean day-night difference for systolic blood pressure displayed a similar effect, with a greater difference for normotensive women (15.7 mm Hg) than for women with preeclampsia (9.4 mm Hg). The Halligan et al. study did not report on any lifestyle differences between the test and control groups during data collection. It was not mentioned whether the control group was asked to follow the lifestyle of the test group, such differences might have affected the participants' circadian rhythm. This fact notwithstanding, these values indicate that the blood pressure fall at night was greater in the normotensive women and smaller in the women with preeclampsia.

Clinical Implications

Circadian rhythm plays an important role in individual health. By understanding how circadian rhythmicity affects the measurements of blood pressure in women with preeclampsia and chronic hypertension, health care professionals will be able to better interpret diagnostic data, decide upon the best method of treatment, and determine the most effective times to treat disease processes (Tolstoi, 1994).

First, the daily blood pressure variability is an important physiologic and clinical feature of individual well-being. The possibility of error cannot be overemphasized when using a casual measurement to identify hypertensive conditions (Ayala et al., 1994; Ferguson et al., 1994; Hughes, 1989; Portaluppi, Waterhouse, & Minors, 1996). Knowledge of circadian rhythm endors-

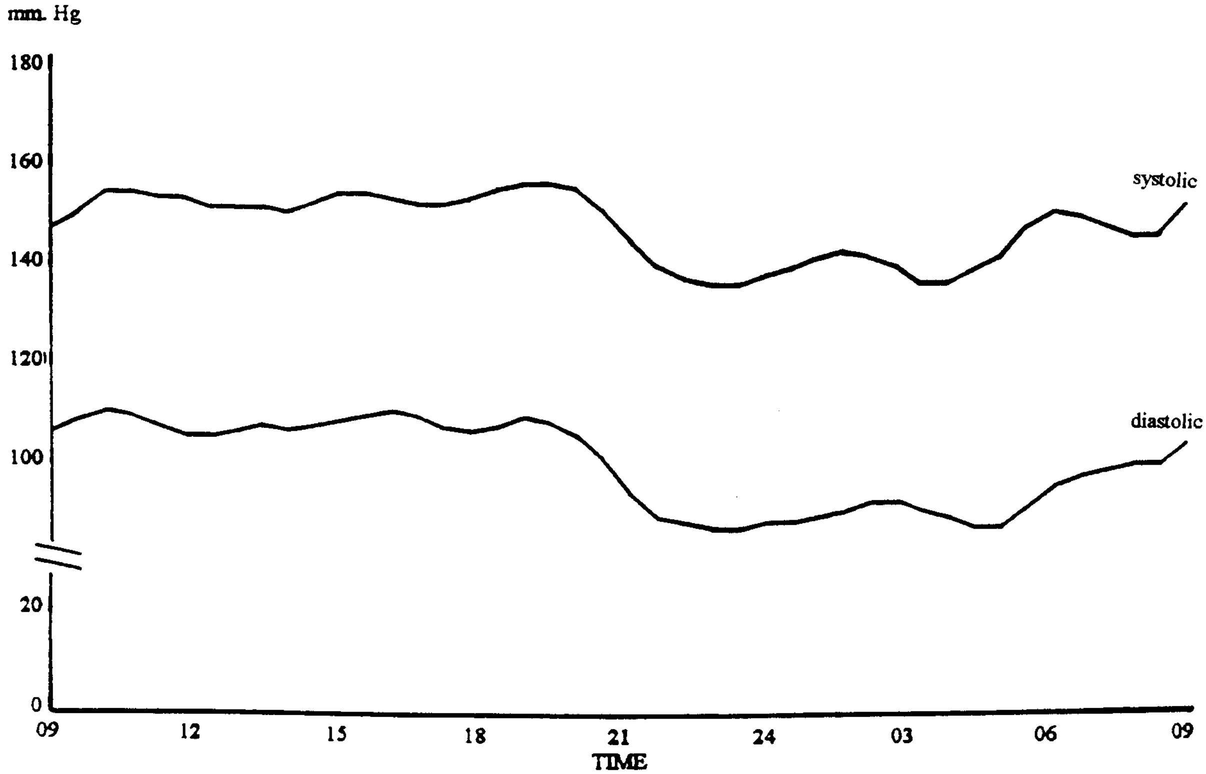

FIGURE 3
Twenty-four hour smoothed record of blood pressure in a case of preeclampsia at 32 weeks gestation. From "Diurnal Blood-Pressure Variation in Pregnancy," by S. A. Seligman. 1971, *Journal of Obstetrics and Gynaecology of the British Commonwealth, 78,* p. 420. Reprinted with permission.

es the clinical practice of taking at least two measurements at a minimum of 6 hours apart to diagnose hypertensive disorders during pregnancy. This knowledge can be applied as evidence for professional nursing practice. The night-shift nurse on a labor and delivery unit, for example, can emphasize consideration of the circadian rhythm when reporting low blood pressure measurements to the next shift. Serial measurements obtained over a 24-hour period provide clinicians with a profile of the patient's daily blood pressure pattern.

Second, researchers have found that 24-hour monitoring of blood pressure during pregnancy provides clinicians with multiple data points for the analysis of normal and abnormal circadian blood pressure patterns (Benedetto et al., 1994; Ferguson et al., 1994; Halligan et al., 1996). Because the adverse effects of cardiovascular conditions are better related to whole-day blood pressure readings, the inclusion of ambulatory blood pressure monitoring in clinical practice can aid in risk assessment. For example, data on 24-hour blood pressure rhythms have been collected in hospital environments. It is not known to what extent the hospital environment contributes to the alteration of circadian rhythm. Under the current health care system, more women with high-risk conditions are being monitored at home. Ambulatory monitoring with telecommunication systems enables nurses to monitor such women at home. These systems may assist nurses in examining to what extent hospital as well as home environments can be adjusted to women's needs, so that women at risk can stay where they feel most comfortable.

Third, researchers studying chronopharmacology, the study of the influence of biologic rhythms on medication pharmacokinetics, effectiveness, and toxicity (Aherne, 1989; Tolsoi, 1994), suggest that the circadian rhythm of physiologic functions, including blood pressure, can influence the effectiveness of drug therapy. For example, a patient with severe preeclampsia may experience a reversed circadian rhythm with an increase in blood pressure during the night or a chronically hypertensive patient may have a greater decrease in blood pressure during sleep. Such patients may benefit from the delivery of medication at certain times of the day. In addition, women on bed rest often are placed in a darkened room 24-hours a day. To what extent does this practice alter their circadian rhythms and interfere with the effectiveness of medication? It is not known whether health care providers are helping or hindering the pos-

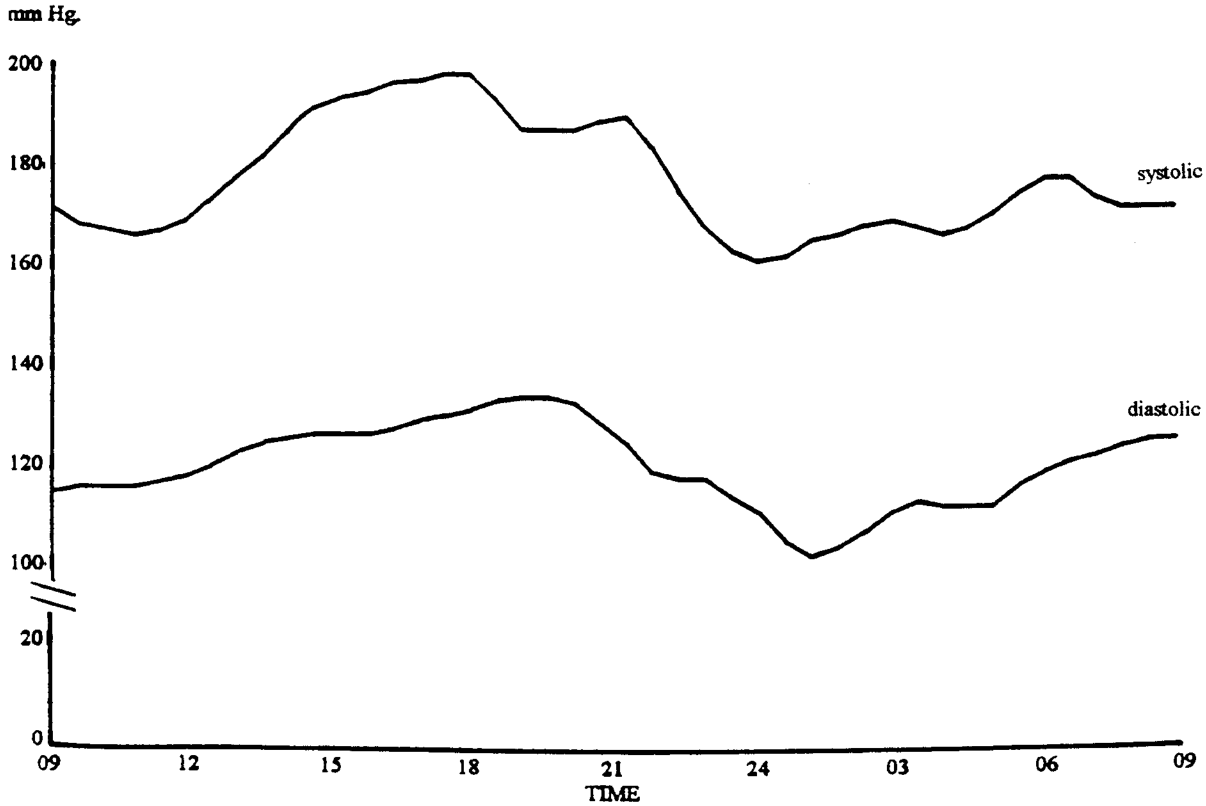

FIGURE 4
Twenty-four hour smoothed record of blood pressure of more severe preeclampsia at 35 weeks gestation. From "Diurnal Blood-Pressure Variation in Pregnancy," by S. A. Seligman. 1971, *Journal of Obstetrics and Gynaecology of the British Commonwealth, 78,* p. 421. Reprinted with permission.

sible decrease in pressure by omitting the day/night variation. Therefore, antihypertensive therapy should be adapted to the demands of blood pressure variability (Oney & Meyer-Sabellek, 1990).

Women with high-risk pregnancies often are placed on bed rest 24 hours a day in a darkened room. To what extent does this practice alter the circadian rhythm and interfere with the effectiveness of medication?

Finally, considering the cost of ambulatory serial measurements, clinical randomized research is needed to identify high-risk populations. On the basis of such studies, women at risk can be targeted for preventive treatment and nursing management.

Conclusion and Future Research

The studies presented on the circadian rhythm of blood pressure during pregnancy have been conducted with differing methods of measurement, under differing conditions, yet some general conclusions can be drawn. In normal pregnancy, the circadian rhythm of blood pressure is the same as in the nonpregnant state, with a nocturnal decrease in blood pressure, especially during sleep (Contard et al., 1993; Halligan et al., 1996; Murnaghan et al., 1980; Redman et al., 1976; Sawyer et al., 1981; Seligman, 1971). This circadian pattern also is observed in people with chronic hypertension (Murnaghan et al., 1980; Redman et al., 1976), and the nocturnal dip is even amplified in some cases (Redman et al., 1976; Sawyer et al., 1981; Seligman, 1971). In patients with mild preeclampsia, however, the nocturnal blood pressure decrease may be less pronounced (Halligan et al., 1996; Murnaghan et al., 1980; Sawyer et al., 1981; Seligman, 1971). Women with severe preeclampsia may show a reversed circadian rhythm with an increase in blood pressure during sleep (Redman et al., 1976; Sawyer et al., 1981) and/or no decrease in nocturnal blood pressure (Sawyer et al., 1981); thus, they are more susceptible to a hypertensive crisis at night.

Further research is needed to determine whether the circadian rhythm alterations are iatrogenic (i.e., bed rest, dimmed room for 24 hours a day, nighttime disturbance in hospitals), pathologic, or a combination of both. The results of such studies will direct whether circadian rhythm disturbance can be used as an indicator to change the client's environment or as a supplemental predictor of preeclampsia. In addition, further research is needed to establish the effects of chronopharmacology on chronic hypertension and preeclampsia.

Knowledge of the potential circadian changes in the human biologic system is a valuable diagnostic tool. Further research is needed to apply this knowledge to practice.

REFERENCES

Aherne, G.W. (1989). An introduction to chronopharmacology. In J. Arendt, D.S. Minors, & J.M. Waterhouse (Eds.), *Biologic rhythms in clinical practice* (pp. 8–19). Boston: Wright.

Arendt, J., Minors, D.S., & Waterhouse, J.M. (1989). Basic concepts and implications. In J. Arendt, D.S. Minors, & J.M. Waterhouse (Eds.), *Biologic rhythms in clinical practice* (pp. 3–7). Boston: Wright.

Ayala, D.E., Hermida, R.C., Cornelissen, G., Brockway, B., & Halberg, F. (1994). Heart rate and blood pressure chronomes during and after pregnancy. *Chronobiologia, 21,* 215–225.

Ayala, D.E., Hermida, R.C., Mojon, A., Fernandez, J.R., & Iglesias, M. (1997). Circadian blood pressure variability in healthy and complicated pregnancies. *Hypertension, 30* (3, Part 2), 603–610.

Baumgart, P. (1991). Circadian rhythm of blood pressure: Internal and external time triggers. *Chronobiology International, 8*(6), 444–450.

Benedetto, C., Marozio, L., Zonca, M., Giarola, M., Maula, V., Melzi, E., Chiarolini, L., Ciochetto, D., Micheletti, L., Coppo, F., Massobrio, M., & Carandente, F. (1994). 24h monitoring of blood pressure in pregnancy: Clinical advantages. *Chronobiologia, 21,* 113–116.

Blackburn, S.K., & Loper, D.L. (1992). *Maternal, fetal and neonatal physiology: A clinical perspective.* Philadelphia: W.B. Saunders.

Binkley, S. (1990). *The clockwork sparrow: Time, clocks and calendars in biological organisms.* Englewood Cliffs, NJ: Prentice Hall.

Clancy, J., & McVicar, A. (1994). Circadian rhythms 1: Physiology. *British Journal of Nursing, 3*(13), 657–661.

Coca, A. (1994). Circadian rhythm and blood pressure control: Physiological and pathophysiological factors. *Journal of Hypertension, 12,* (Suppl. 5), S13–S21.

Consensus report. (1990). National high blood pressure education program working group report on high blood pressure in pregnancy. *American Journal of Obstetrics and Gynecology, 163,* 1691–1712.

Contard, S., Chanudet, X., Coisne, D., Battistella, B., Marichal, J., Pitiot, M., deGaudemaris, R., & Ribstein, J. (1993). Ambulatory monitoring of blood pressure in normal pregnancy. *American Journal of Hypertension, 6,* 880–884.

Cruikshank, D.P., Wigton, T.R., & Hays, P.M. (1996). Maternal physiology in pregnancy. In S.G. Gabbe, J.R. Niebyl, & J.L. Simpson (Eds.), *Obstetrics: Normal and problem pregnancies* (3rd ed., pp. 91–109). New York: Churchill Livingstone.

Czeisler, C.A., Johnson, M.P., Duffy, J.F., Brown, E.N., Ronda, J.M., & Kronauer, R.E. (1990). Exposure to bright light and darkness to treat physiologic maladaptation to nightwork. *New England Journal of Medicine, 322*(18), 1253–1259.

Delea, C.S. (1979). Chronobiology of blood pressure. *Nephron, 23,* 91–97.

Dunlap, J.C., Loros, J.J., Aronson, B.D., Merrow, M., Crosthwaite, S., Bell-Pedersen, D., Johnson, K., Lindgren, K., & Garceau, N.Y. (1995). The genetic basis of the circadian clock: Identification of frq and FRQ as clock components in neurospora. In *Circadian clocks and their adjustment* (Ciba Foundation Symposium, 183, pp. 3–25). New York: John Wiley and Sons.

Efinger, J., Nelson, L.C., & Walsh-Starr, J.M. (1995). Understanding circadian rhythms: A holistic approach to nurses and shift work. *American Holistic Association, 13*(4), 306–322.

Ferguson, J.H., Neubauer, B.L., & Shaar, C.J. (1994). Ambulatory blood pressure monitoring during pregnancy: Establishment of standards of normalcy. *American Journal of Hypertension, 7,* 838–843.

Gallery, E.D.M., Hunyor, S.N., Ross, M., & Gyory, A.Z. (1977). Predicting the development of pregnancy-associated hypertension: The place of standardized blood pressure measurement. *Lancet,* 1273–1275.

Gillette, M.U., Medanic, M., McAuthur, A.J., Liu, C., Ding, J.M., Faiman, L.E., Weber, E.T., Tcheng, T.K., & Gallman, E.A. (1995). Intrinsic neuronal rhythms in the suprachiasmatic nuclei and their adjustment. In *Circadian clocks and their adjustment* (Ciba Foundation Symposium, 183, pp. 134–153). New York: John Wiley and Sons.

Halligan, A., Shennan, A., Lambert, P.C., deSwiet, M., & Taylor, D.J. (1996). Diurnal blood pressure difference in the assessment of preeclampsia. *Obstetrics and Gynecology, 87,* 205–208.

Hermida, R.C., Ayala, D.E., Mojon, A., Fernandez, J.R., Silva, I., Ucieda, R., & Iglesias, M. (1997). High sensitivity test for the early diagnosis of gestational hypertension and preeclampsia, I: Predictable variability of cardiovascular characteristics during gestation in healthy and hypertensive pregnant women. *Journal of Perinatal Medicine, 25,* 101–109.

Honnebier, M.B.O.M., & Nathanielsz, P.W. (1994). Primate parturition and the role of the maternal circadian system. *European Journal of Obstetrics, Gynecology, and Reproductive Biology, 55,* 193–203.

Hughes, M. (1989). *Body clock: The effects of time on human health.* New York: Facts on File.

MacGillivray, I., Rose, G.D., & Rowe, D. (1969). Blood pressure survey in pregnancy. *Clinical Science, 37,* 395–407.
Miller, B.F., & Keane, C.B. (1987). *Encyclopedia and dictionary of medicine, nursing, and allied health* (4th ed.). Philadelphia: W.B. Saunders.
Minors, D.S., & Waterhouse, J.M. (1981). *Circadian rhythms and the human.* London: Wright PSG.
Moore-Ede, M.C., Sulzman, F.M., & Fuller, C.A. (1982). *The clocks that time us: Physiology of the circadian timing system.* Cambridge, MA.: Harvard University Press.
Murnaghan, G.A., Mitchell, R.H., & Ruff, S. (1980). Circadian variation of blood pressure in pregnancy. In J. Bonnar, I. MacGillivray, & M. Symonds (Eds.), *Pregnancy hypertension* (pp. 107–112). Baltimore: University Park Press.
Oney, T., & Meyer-Sabellek, W. (1990). Variability of arterial blood pressure in normal and hypertensive pregnancy. *Journal of Hypertension, 8*(Suppl. 6), S77–S81.
Perloff, D., Sokolow, M., & Cowan, R. (1983). The prognostic value of ambulatory blood pressure. *Journal of the American Medical Association, 249,* 2792–2798.
Portaluppi, F., Waterhouse, J., & Minors, D. (1996). The rhythms of blood pressure in humans: Exogenous and endogenous components and implications for diagnosis and treatment. *Annals of New York Academy of Sciences, 783,* 1–9.
Ralph, M.R., & Hurd, M.W. (1995). Circadian pacemakers in vertebrates. In *Circadian clocks and their adjustment* (Ciba Foundation Symposium, 183, pp. 67–87). New York: John Wiley and Sons.
Redman, C.W.G., Beilin, L.J., & Bonnar, J. (1976). Variability of blood pressure in normal and abnormal pregnancy. In M.D. Lindheimer, A.I. Katz, & F.P. Zuspan (Eds.), *Hypertension in pregnancy* (pp. 53–60). New York: John Wiley and Sons.
Sawyer, M.M., Lipshitz, J., Anderson, G.D., Dilts, P.V., & Halperin, L. (1981). Diurnal and short-term variation of blood pressure: Comparison of preeclamptic, chronic hypertension, and normotensive patients. *Obstetrics and Gynecology, 58,* 291–296.
Seligman, S.A. (1971). Diurnal blood pressure variation in pregnancy. *Journal of Obstetrics and Gynecology of the British Commonwealth, 78,* 417–422.
Seron-Ferre, M., Ducsay, C.A., & Valenzuela, G.J. (1993). Circadian rhythms during pregnancy. *Endocrine Reviews, 14*(5), 594–609.
Smeltzer, S.C., & Bare, B.G. (1992). *Brunner and Suddarths'* textbook of medical-surgical nursing, (7th ed.). Philadelphia: J.B. Lippincott.
Thomas, S.A., & DeKeyser, F. (1996). Blood pressure. In J.J. Fitzpatrick, & J. Norbeck, *Annual review of nursing research.* New York: Springer Publishing Company.
Tolstoi, L.G. (1994). A review of chronobiology and chronopharmacology. *Journal of Practical Nursing, 44*(1), 47–55.
Weber, M.A., Drayer, J.I.M., Nakamura, D.K., & Wyle, F.A. (1984). The circadian blood pressure pattern in ambulatory normal subjects. *American Journal of Cardiology, 54,* 115–119.

Cheryl D. Larry is a graduate of the University of Michigan School of Nursing, Ann Arbor, and a labor and delivery clinical nurse specialist at Henry Ford Hospital in Detroit, MI.

SeonAe Yeo is an associate professor at the University of Michigan School of Nursing, Division of Health Promotion and Risk Reduction, Ann Arbor.

Address for correspondence: Cheryl D. Larry, RN, CNM, CNS, Henry Ford Hospital, Labor & Delivery Unit, 3rd Floor West Pavilion, 2799 West Grand Boulevard, Detroit, MI 48202-2689.