Factors Controlling Plasma Renin and Aldosterone During Pregnancy

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SUMMARY The response of plasma renin activity (PRA) and plasma aldosterone (PA) to change in sodium intake was evaluated in pregnant women during the third trimester. After 7 days on a 10 mEq sodium diet, PRA rose from 20.6 ± 6.2 to 59.6 ± 11.6 ng/ml/hr and PA from 47 ± 11 to 127 ± 27 ng% in pregnant women compared to PRA from 5 ± 1.2 to 18.9 ± 5.2 ng/ml/hr and PA from 7.7 ± 1 to 42 ± 3 ng% in nonpregnant controls. Pregnant women conserved sodium normally with urinary sodium excretion and weight loss similar to nonpregnant women. After 6 days on a 300 mEq sodium intake, PRA and PA in pregnant women were significantly higher, 10.2 ± 1.4 ng/ml/hr and 22 ± 3 ng%, respectively, compared to 1.5 ± 0.3 ng/ml/hr and 7.3 ± 1 ng% in controls. On both low- and high sodium intake there was a positive correlation between PRA and PA in pregnant women. Plasma prostaglandin E (PGE) was 0.45 ± 0.06 ng/ml in pregnant women compared to 0.1 ± 0.01 ng/ml in control women (p < 0.01) and urinary PGE excretion was 2780 ± 357 ng/24 hr in 28 pregnant women compared to 1191 ± 142 ng/24 hrs (p < 0.01) in 14 nonpregnant controls. These findings indicate that although renin and aldosterone secretion respond to change in sodium intake in pregnancy, the cause of the increased renin secretion of pregnancy may be secondary to the increase that occurs in prostaglandin synthesis. (Hypertension 1: 410–415, 1979)

KEY WORDS • renin • aldosterone • pregnancy • toxemia • prostaglandin E • sodium balance

PREGNANCY is associated with a striking increase in renin and aldosterone secretion. This has been attributed to either a salt-losing tendency induced by the increase in glomerular filtration rate (GFR) and progesterone secretion, orthostatic pooling in the extremities, or increased shunting of blood in the uterine circulation. However, blood volume, cardiac output, renal blood flow, and GFR all increase in pregnancy, which argues against functional volume depletion. In addition, the rise in renin secretion occurs in the first trimester before a great increase in uterine size or blood flow. Some studies have suggested no correlation between plasma renin activity (PRA) and plasma aldosterone (PA) in pregnancy, which suggests that factors other than sodium balance control renin secretion in pregnancy. To evaluate these questions, studies of PRA and PA were carried out in pregnant women in their third trimester on a low- and high-sodium intake. Since decreased sensitivity to angiotensin occurs during human pregnancy and renal prostaglandin synthesis may affect renin secretion, plasma and urinary PGE were also measured.

Methods

Normotensive women in their third trimester with no past history of renal or cardiovascular disease were admitted to the Clinical Research Center and placed on either a 10 or 300 mEq sodium, 100 mEq potassium diet. Plasma renin and aldosterone were obtained before arising and at noon. Daily plasma electrolytes and 24-hour urine samples were obtained for creatinine clearance, urinary sodium and potassium determination. Nonpregnant hospital employees served as controls and were placed on the same diets, but were allowed to leave the metabolic unit during working hours. Plasma renin activity was measured by radioimmunoassay according to the method of Haber after incubation of plasma for 3 hours at pH 5.5.
RENIN AND ALDOSTERONE DURING PREGNANCY

WEIGHT CHANGE

Plasma and urinary aldosterone and prostaglandin E (PGE) were measured by radioimmunoassay methods previously reported from this laboratory. 

Results

On the first day of the study, pregnant women had higher supine PRA, 12 ± 3 ng/ml/hr, than nonpregnant women, 2.4 ± 0.9 ng/ml/hr (p < 0.01). After being upright for 4 hours, PRA increased in pregnant women to 18 ± 3 compared to 4 ± 0.8 ng/ml/hr in control women. Plasma aldosterone increased with standing from 20 ± 3 to 36 ± 7 ng% in the pregnant women compared to from 6.3 ± 1 to 7.7 ± 0.8 ng% in controls.

On a daily 10 mEq sodium intake, pregnant and nonpregnant women came into sodium balance as shown in figure 1. By Day 4 pregnant and nonpregnant women had similar sodium excretion but over the next 7 days nonpregnant women had greater mean sodium loss (280 mEq) than pregnant women (215 mEq), although the difference was not statistically significant. Weight loss (1.5 kg) was similar over the 7-day period in both groups. Creatinine clearance was higher in pregnant women, 133 ± 4, compared to 117 ± 4 ml/min in nonpregnant women (p < 0.05) and no change occurred in either group during sodium restriction. On the low sodium diet pregnant and nonpregnant women had increased PRA and aldosterone levels (fig. 2); PRA rose in nonpregnant women from 5 ± 1.2 on Day 1 to 18.9 ± 5.2 ng/ml/hr (p < 0.01) on Day 7 and PA increased from 7.7 ± 1 to 42 ± 3 ng% (p < 0.01). In pregnant women, PRA rose from 20.6 ± 5 to 59.6 ± 11 ng/ml/hr (p < 0.01) and plasma aldosterone from 47 ± 11 to 127 ± 27 ng% (p < 0.01) on Day 7. Urinary aldosterone excretion in pregnant women rose from 66 ± 10 on Day 1 to 225 ± 37 μg/24 hrs (p < 0.01) on Day 7.

On the 300 mEq sodium intake, both groups were in sodium balance by Day 5. Pregnant women retained 170 mEq of sodium with a 1.2 kg weight gain. No weight gain occurred in controls as they came into sodium balance on the first day of the 300 mEq sodium intake. After 7 days of a 300 mEq sodium intake, serum potassium was unchanged in both groups. However, by Day 6, urinary sodium excretion was similar in both groups but PRA was 10.2 ± 1.4 ng/ml/hr and aldosterone 22 ± 3 ng% in pregnant women compared to 1.5 ± 0.3 ng/ml/hr and 7.3 ± 1 ng% in nonpregnant women. Figure 3 plots the supine PRA and PA in pregnant and nonpregnant women on the 300 mEq sodium intake.
Figure 4 demonstrates the correlation in pregnant women of mean PRA and PA over the 6 days of high sodium and 7 days of low sodium intake. The correlation coefficient was $r = 0.95$ on the low and $r = 0.78$ on the high sodium diet. The slope of the regression was similar in the pregnant and nonpregnant women on a low sodium intake. On the high sodium intake in the nonpregnant women, no significant change in PRA or PA occurred due to the initial high urinary sodium and low PRA and PA in these women on the first day of the study.

After 6 days of a 300 mEq sodium diet, two women from each group were given 2 liters of normal saline intravenously for 2 consecutive days during which time they remained recumbent. Despite bed rest and 4 liters of saline, the pregnant women had PRA of 3.5 compared to $0.3 \pm 0.1$ ng/ml/hr in nonpregnant women and their PA level was $12 \pm 1$ compared to $6 \pm 2$ ng%. Thus, upright posture is not necessary for persistence of renin secretion in pregnancy. The GFR was significantly higher in the pregnant women, $154 \pm 12$, compared to $115 \pm 5$ ml/min in nonpregnant women before the start of the high salt intake and in neither group did the GFR increase during sodium loading.

Figure 5 shows plasma prostaglandin E in 23 pregnant women in their third trimester and 19 nonpregnant women.
nant women. Prostaglandin E was 0.45 ± 0.06 compared to 0.1 ± 0.01 ng/ml in control women (p < 0.01). Twenty-four-hour urine for PGE, obtained from 28 pregnant women on unrestricted sodium intake, was 2780 ± 357 compared to 1191 ± 142 ng/24 hrs in 14 nonpregnant women (p < 0.025) (fig. 6).

Discussion

Previous studies of pregnant women have consistently demonstrated an increase in renin and aldosterone secretion. However, there have been discrepant findings regarding their responsiveness to changes in sodium intake. Some but not all studies have demonstrated a variation with changes in sodium intake. We found a significant correlation between PRA and PA on both a high and low sodium intake. Although on both high and low sodium intake PRA and PA were higher in pregnant women, the slope of the regression lines was similar for both pregnant and nonpregnant women on the low sodium diet (fig. 4).

The cause of the elevated PRA in pregnancy has been attributed to increased progesterone secretion, a known aldosterone antagonist. Progesterone secretion increases in the first trimester and parallels aldosterone secretion. When given to normal subjects or to patients with adrenal insufficiency on mineralocorticoid replacement, progesterone increases sodium excretion, and when applied to the isolated toad bladder it reduces sodium transport by displacing aldosterone from its binding site. In not all studies of pregnancy, however, has a correlation between plasma progesterone and plasma aldosterone been found. It is also difficult to explain the sodium retention, expansion of maternal extracellular volume, on the basis of antagonism to aldosterone and a tendency to natriuresis during pregnancy. Landau, and Lugibihl, failed to observe a natriuresis in pregnant women given progesterone, and women with Addison's disease do not require added mineralocorticoid replacement during pregnancy. Thus, mineralocorticoid antagonism does not appear to be a prominent feature of pregnancy, although the failure to develop hypokalemia with increased aldosterone secretion and normal sodium intake might be explained by the increased progesterone secretion. Hypokalemia associated with primary aldosteronism has been ameliorated during pregnancy.

The elevation of PRA, in spite of a high sodium intake, points to factors other than sodium that control renin secretion in pregnancy. Although compression of the inferior vena cava by the gravid uterus in late pregnancy might increase renin secretion, the elevated PRA prior to arising and after intravenous saline and

![Figure 5. Plasma prostaglandin E (PGE) in pregnant women in their third trimester and nonpregnant women.](http://hyper.ahajournals.org/)

\[p < 0.001\]
cretion is thought to represent renal synthesis since the

propriately to change in sodium intake in our studies

sodium intake and does not normally enter the mater-

Figure 6. Urinary prostaglandin E (PGE) excretion in

pregnant (third trimester) and nonpregnant women.

recumbency for 2 days argues against posture being a

major component in the increased renin secretion. The

finding that pregnant women retain more sodium and
take longer to come into balance on a high sodium in-
take has been noted by others. It may be caused by an

increased venous capacity in pregnancy requiring
greater extracellular expansion to achieve balance. How-

ever, by Day 4, urinary sodium was similar in both
groups but PRA and PA remained higher in the

pregnant women.

Increased estrogen secretion during pregnancy in-

creases renin substrate concentration but this is not an

adequate explanation for the elevated PRA. No

significant increase in PRA usually occurs in women
taking oral contraceptives containing estrogen. It may be

probably due to feedback suppression of renin secre-

tion. However, in pregnancy there is an increase in

plasma renin, renin substrate, and angiotensin con-

centration.

The uterus and amniotic fluid are potential sources

of renin in pregnancy. Day et al. found that human

amniotic fluid contained mainly "big renin" since
dialysis at pH 3.3 greatly increased renin activity. Exper-

mental evidence in animals suggests that uterine

renin concentration does not respond to change in

sodium intake and does not normally enter the mater-

nal circulation. The fact that PRA responded ap-

propriately to change in sodium intake in our studies

makes it unlikely that uterine renin is a major source

of PRA in third-trimester-pregnant women or that

"big renin" activated by incubation at pH 5.5 con-

tributes significantly to the hyper-reninemia of

pregnancy.

The sources of the increased plasma and urinary

PGE in pregnant women is unclear. Urinary PGE ex-

creton would increase plasma PGE. In-

fusions of PGE into the renal artery do not increase

urinary PGE excretion. However, extraordinary

concentration of PGE have been found in the uterine

vein of pregnant rabbits. Whether uterine PGE secre-

tion would increase plasma PGE concentration
depends upon the extent to which PGE escapes metab-

olism during transit through the pulmonary circu-

lation. Studies in the cat and dog indicate that 90-95% of

PGE is metabolized in one passage through the pulmon-

ary capillary bed but in humans only 65% of PGE injected

into the right ventricle is metabolized in the pulmonary

circulation. Thus, an increase in uterine PGE synthesis
could possibly elevate plasma PGE concentration.

The role of increased PGE synthesis in pregnancy is

unknown. The uterus can synthesize prostaglandins of

the E and F series and both may have a role in con-

trolling uterine motility. Prostaglandin-inhibiting

drugs reduce uteroplacental blood flow in the pregnant

rabbit although autoregulation of uterine blood flow

is independent of prostaglandin synthesis. Uterine

synthesis of PGE might be necessary for new blood

vessel growth and development in the uterus and

placenta during pregnancy. The vasodilation and in-

crease in blood volume induced by vasodilation would

be a teleological advantage in pregnancy; protecting

against hypotension and volume depletion if

hemorrhage should accompany delivery.

Increase PGE synthesis may also be a factor in

the increase in renin secretion of pregnancy. Stimulation

of renal prostaglandin synthesis by administration of

arachidonic acid to rabbits and dogs increases renin

secretion and indomethacin reduces renin secre-

tion. This effect appears to be independent of

change in renal blood flow since prostaglandin syn-

thesis appears necessary for renin secretion during in

vitro studies of renal cortical cells.

Synthesis of PGE may cause the insensitivity to

angiotensin that occurs with pregnancy. Prostaglandin

analogons and inhibition of PGE synthesis enhances

the pressor effect of angiotensin and norepinephrine.

Angiotensin antagonism has been demonstrated in

human pregnancy as early as 10-12 weeks of

gestation. Everett et al. have reported that indomethacin

and aspirin reverse this insensitivity. Pregnancy could be

similar to Bartter's syndrome where insensitivity to

angiotensin, induced by PGE, is thought to cause compensatory increase in renin secre-

tion. Like pregnant women, patients with Bartter's

syndrome have elevated PRA levels which vary with

gestation. Stimulation of PGE synthesis may also be a factor in the

increase in renin secretion of pregnancy. Stimulation

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tion. Like pregnant women, patients with Bartter's

syndrome have elevated PRA levels which vary with

change in sodium intake and are not suppressed in

response to volume expansion. Urinary PGE excre-

tion in Bartter's syndrome has been reported elevated
to values similar to the results we found in pregnant

women.

One might speculate on the potential role of PGE

synthesis in the development of hypertension with tox-

emia. Although PRA is variable in toxemia, angioten-
sin sensitivity increases and precedes the development
of hypertension. Conceivably, increased sensitivity to angiotensin with development of toxemia represents a decrease in PGE synthesis with resultant imbalance of the renin-angiotensin-PGE axis. Serial measurements of urinary PGE throughout pregnancy are needed to determine if changes in angiotensin sensitivity with toxemia can be correlated with urinary PGE excretion.

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