The spatial vectorcardiogram in diagnosis

D. EMSLIE-SMITH   K. G. LOWE

Department of Medicine, University of Dundee

THE spatial vectorcardiogram is an approximate model of the moment-to-moment changes in direction and magnitude of the unbalanced electrical activity of the heart in three dimensions. In practice it is recorded from the surface of the human thorax through specially placed electrodes, so the information it records is essentially similar to that recorded by scalar (surface) electrocardiography. Although the basic electrical information may be similar, it is, however, displayed in a different manner by the two different methods. Each method of display can emphasize particular features of cardiac excitation.

In a survey of 500 records and 10 years' experience of clinical and experimental vector-cardiography we have found there are at least two aspects of the cardiac electrical activity that are better demonstrated in the QRS loop of the vectorcardiogram (VCG) than in the QRS complex of the scalar electrocardiogram (ECG). The first involves directional properties that are the equivalent of inconspicuous phase-relationships between simultaneously recorded complexes in scalar leads (Fig. 1). The superiority of the spatial

VCG in demonstrating this aspect is gradually being appreciated by electrocardiographers. The second aspect, which does not seem to be so well appreciated, concerns the speed of inscription of various parts of the scalar QRS complex or the QRS vector loop.

Scalar records are often made by direct-writing machines that tend to slur the complexes and are greatly influenced by factors such as the heat of the stylus. Even in good photographic records the speed of inscription of different parts of the complex may be very hard to estimate. The simple VCG, being a plot of voltage against voltage, does not by itself allow an appreciation of time. In most modern vectorcardiographs, however, timing is introduced by an interruption of the tracing by a regular blanking-pulse. This can only be seen while the cathode beam is moving, but during the inscription of the QRS loop changes in the rate of inscription are very readily appreciated. When the beam moves slowly the blanking-pulses are close together; when it moves fast they are wide apart. The speed of inscription can only be accurately assessed from consideration of the three-dimensional spatial VCG and not from the QRS loop projected on a single plane, for example the frontal, alone.

We present here some examples of the help afforded in diagnosis by the spatial VCG through its ability to demonstrate properties of speed and direction during the electrical excitation of the ventricles.

Abnormal direction of inscription

Normally the vectors resulting from the initial forces of ventricular excitation are directed forward, downward and to the right and then inscribe an anticlockwise loop in the horizontal projection. If, however, the unbalanced electrical activity during the first few milliseconds is altered by a loss of excitable myocardium antero-laterally the initial crochet of the QRS loop in the horizontal plane may be inscribed clockwise. This very important clue to antero-lateral myocardial damage may not be apparent in scalar leads.
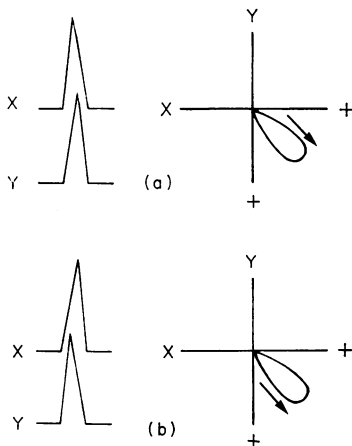
Figure 2 shows the scalar ECG and frontal

FIG. 1. The upstrokes of the R waves in the orthogonal scalar leads X and Y start simultaneously but are inscribed at different rates. In (a) the peak of R in lead X precedes that in lead Y so the vector loop is inscribed clockwise; in (b) the peak of R in lead Y precedes that in lead X so the loop is anticlockwise.
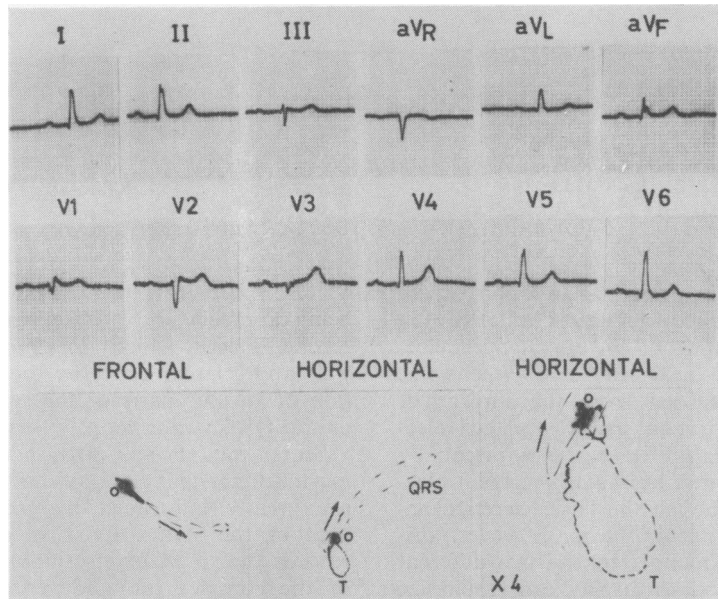
FIG. 2. Antero-lateral myocardial infarction. There has been a loss of electrical forces anteriorly and to the left with resulting clockwise inscription of the QRS loop in the horizontal plane. O = origin, QRS = QRS loop, T = T loop, arrows indicate the direction of inscription.
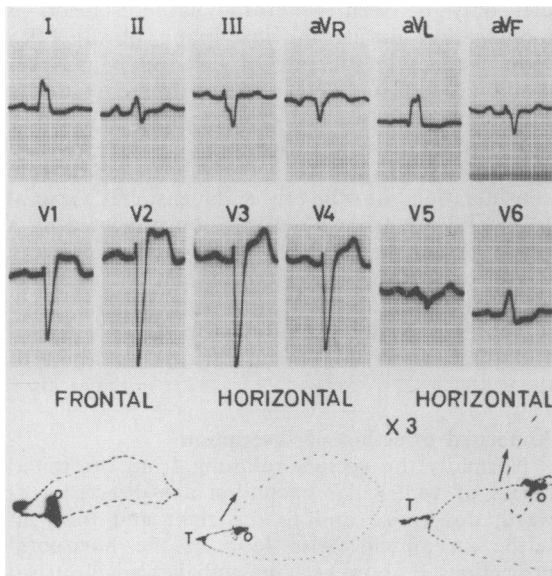

FIG. 3. Infarction of the left side of the interventricular septum with left bundle-branch block. The initial crochet is directed to the right and the whole QRS loop is inscribed clockwise in the horizontal plane. In other respects the loop is that of left bundle-branch block.

and horizontal plane VCGs of a man of 44 years with acute pulmonary oedema. Apart from a rather abnormal low voltage complex in lead V_3 the scalar ECG is unhelpful. On the other hand, the horizontal VCG shows the whole QRS loop inscribed in an abnormal clockwise direction, the initial crochet being directed forwards and to the right. This suggests lack of early electrical activity antero-laterally and is compatible with antero-lateral infarction or other damage.

Figure 3 shows the scalar and vector records of a woman of 53 years who presented with congestive cardiac failure and a history of 2 years' chest pain and breathlessness on exertion. The scalar ECG shows the pattern of complete left bundle-branch block, the only unusual feature being the complex in lead V_5. Again, however, the horizontal QRS loop is inscribed entirely in a clockwise direction with an initial crochet directed forwards and to the right. This vectorcardiographic pattern is characteristic of left bundle-branch block complicating a left septal infarction (Scott, 1965).

Abnormal speed of inscription

In normal ventricular excitation the spatial vectorcardiogram is usually more slowly inscribed during the first and last 15 msec than during the intervening part of the loop. Certain abnormalities of ventricular excitation are characterized by abnormally slow initial or terminal
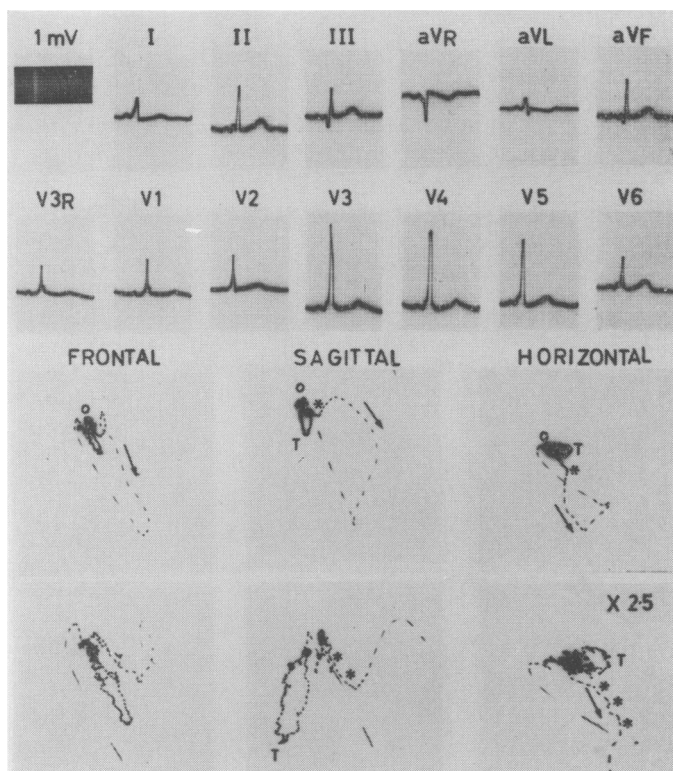
FIG. 4.   Type A (left) ventricular pre-excitation. There is a very
slow conduction velocity of the initial forces (delta vector)
directed anteriorly. Asterisks denote the delta vector.

crochets, notably ventricular pre-excitation, right bundle-branch block and post-infarction conduction disturbances.

Ventricular pre-excitation gives rise to the delta wave in scalar records. In the spatial VCG this is represented by an abnormally slow inscription of the initial part of the loop. Fig. 4 shows the scalar and vector records from a patient with Type A (left) ventricular pre-excitation. The abnormal speed of inscription and direction of the first part of the loop are easily seen and can be contrasted with the equivalent part of the loop in Fig. 5. The slurred upstroke of R in right precordial leads in patients with right ventricular hypertrophy may superficially resemble the delta wave of Type A pre-excitation, especially when the PR interval is at the lower limit of normal, but inspection of the VCGs readily differentiates the two patterns (Figs. 4 and 5).

An abnormally slow inscription of the terminal part of the QRS loop is seen in right bundle-branch block. Fig. 6 shows the records from a patient with Type B (right) ventricular

pre-excitation and right bundle-branch block. This unusual combination of abnormalities is responsible for the abnormal slowing of both the initial and terminal parts of the QRS loop (Robertson *et al.*, 1963). The full diagnosis would be difficult from an inspection of scalar records alone.

Intraventricular conduction defects, other than classical bundle-branch block, may be due to myocardial infarction or cardiomyopathy. The commonest is post-infarction block, either *intra-infarction* block, characterized by delay in the initial ventricular forces, or *peri-infarction* block, characterized by terminal delay (Castellanos & Lemberg, 1966). These are much more clearly demonstrated by vector than by scalar methods. Fig. 7 shows an example of peri-infarction block in an elderly woman with ischaemic heart disease. The VCG in the frontal and sagittal planes shows a loss of the normal inferior forces and strongly suggests a diaphragmatic infarction despite the presence of small *r* waves in leads II, III and aVF. As is characteristic of peri-infarction block the very slow terminal part of
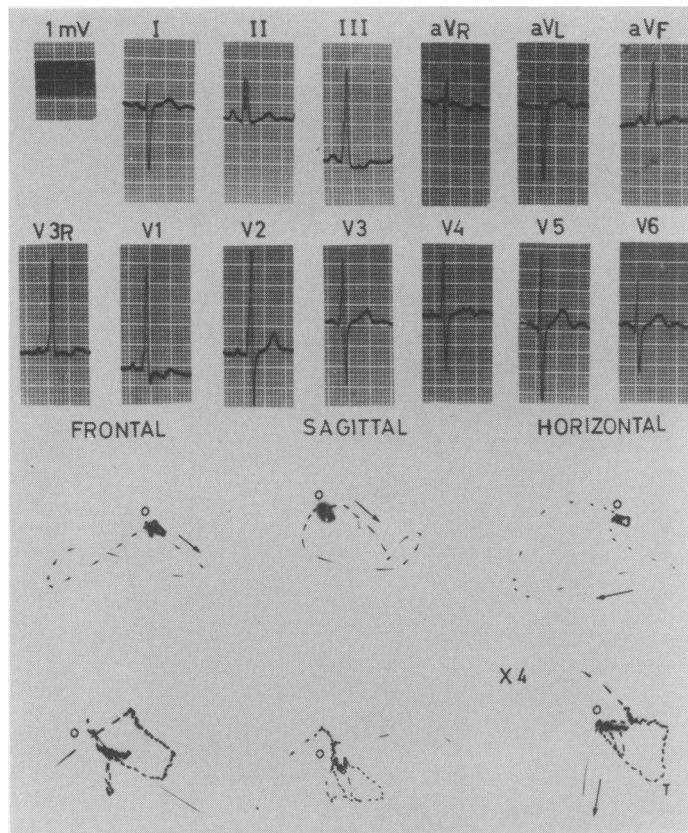
FIG. 5. Right ventricular hypertrophy with the PR interval at the lower limit of normal (0·12 sec) and a slurred upstroke of R in right chest leads. The VCG shows normal conduction velocities.
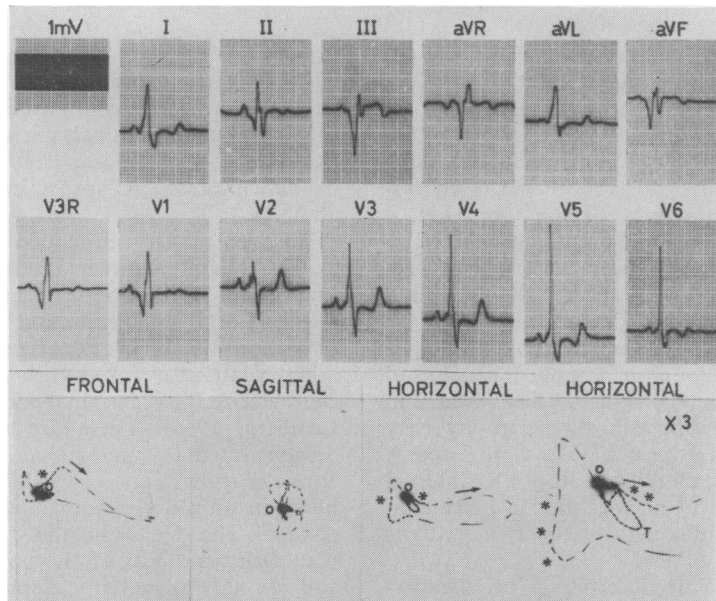

FIG. 6. Type B (right) ventricular pre-excitation and right bundle-branch block. Asterisks mark the slow conduction at the beginning (delta vector) and end (R.BBB) of the QRS loop.
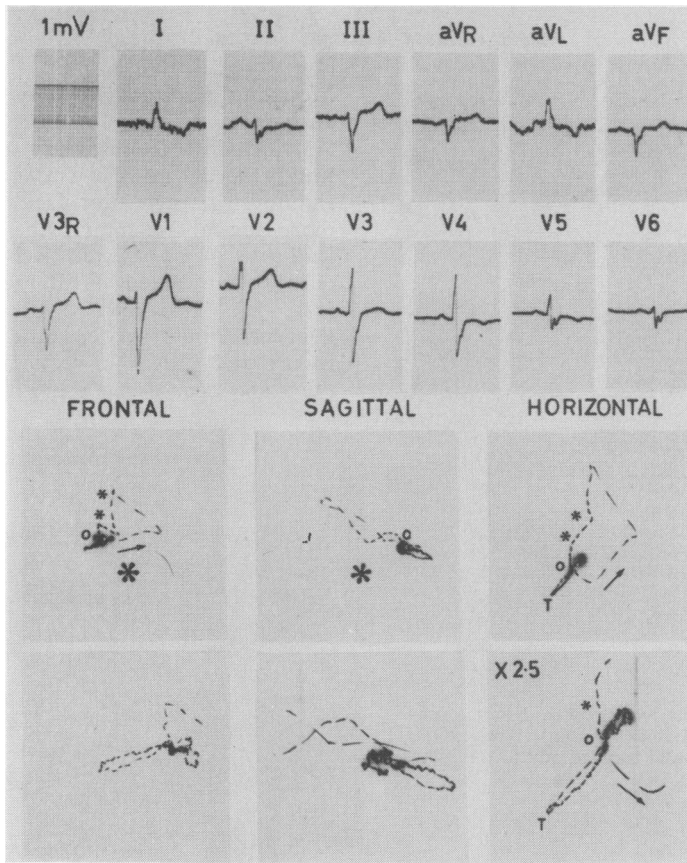
FIG. 7. Inferior (diaphragmatic) infarction with peri-infarction block. The large asterisk indicates the absence of inferior forces and the small asterisks mark the slow inscription of the terminal part of the QRS loop.

the QRS loop lies in the quadrant opposite the infarcted area.

Vectorial interpretation

The spatial VCG is determined by the spread of electrical activity through the myocardium. Its interpretation must similarly be made in terms of altered spread of excitation.

Abnormalities of speed of inscription give information about altered conduction velocities. Abnormal directions of inscription reflect abnormalities in the balance of forces in the ventricles. Thus both addition of forces, as in hypertrophy, and subtraction of forces, as in infarction, can alter the balance.

This kind of interpretation can be applied to the solution of clinical problems. For example, the interpretation of an RSR' pattern in scalar records from right chest-leads is sometimes difficult, but the spatial VCG can help.

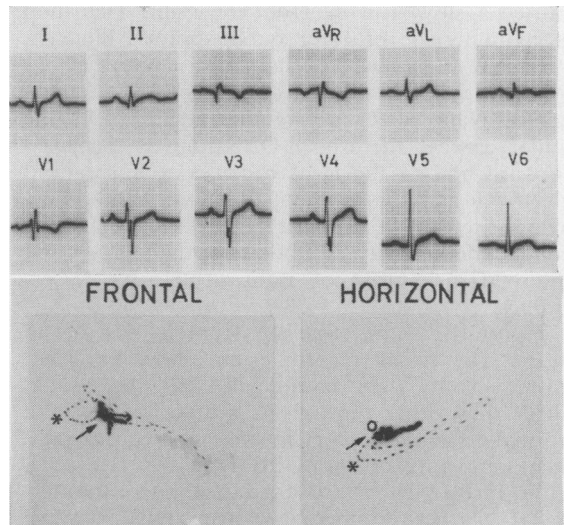Figure 8 shows records from a man of 21

FIG. 8. Right bundle-branch block. The terminal part of the QRS loop is displaced anteriorly and to the right with a slow terminal conduction velocity (asterisk).
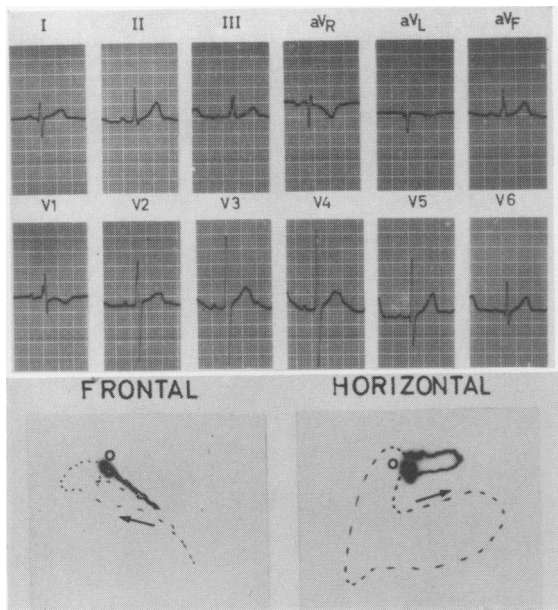
FIG. 9. Right ventricular hypertrophy. Normal conduction velocities. Apart from the initial crochet the whole QRS loop is displaced forward and to the right.

Mounting electrocardiograms for vectorial analysis

In Britain it is customary to mount the twelve-lead records of the scalar ECG around the Einthoven triangle. For vectorial analysis it seems more logical to mount the records along the lead axes of a corrected twelve-lead spatial reference system based on Burger's scalene triangle (Fig. 11). This method of display emphasizes the correlation between the vector and scalar forces and aids the vectorial interpretation of the scalar records.
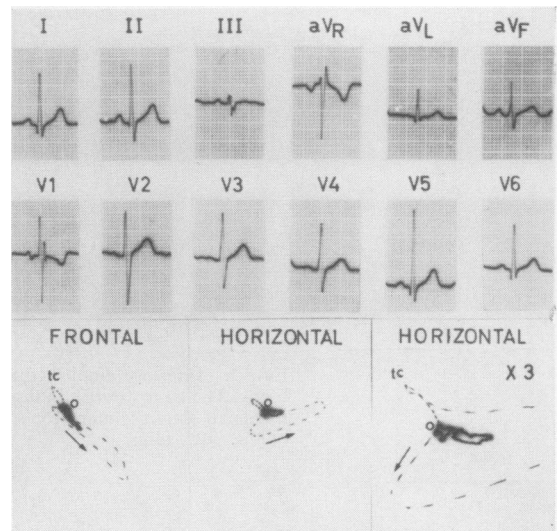

FIG. 10. A normal QRS loop whose long axis is rotated rather far backward, bringing the terminal crochet (tc) into the axis of right chest leads.

years with an atrial septal defect. The spatial VCG shows that late unbalanced electrical forces situated anteriorly and to the right have dis-placed the terminal part of the loop in that direction and a slow conduction velocity has caused a slow 'run in' from the right. This loop is characteristic of right bundle-branch block.

Figure 9 shows records from a boy of 11 years with congenital heart disease. The horizontal plane VCG shows that apart from the initial crochet the whole QRS loop is displaced forward and to the right because of unbalanced electrical activity in that direction. While here again there is a 'run in' from the right, the conduction velocity is not abnormally slow and the pattern is that of right ventricular hypertrophy.

Figure 10 shows tracings from a boy of 15 years. The scalar records again show an RSR' pattern from right chest-leads, but the spatial VCG shows that the late R is associated with a normal terminal crochet in the vectorcardiogram. The long axis of the QRS loop is oriented a little further backward than usual, so the terminal crochet produces a conspicuous R wave in lead V_1. There is no abnormality of conduction velocity or of balance of forces. It is a normal record.

Conclusion

Because the QRS loop of the spatial vectorcardiogram represents the unbalanced electrical activity of the ventricles it gives information about the spread of excitation through the ventricular muscle. Its importance in electrocardiographic theory, in research and in teaching is now accepted. It can also help in the elucidation of ambiguous scalar ECGs in clinical cardiological practice.
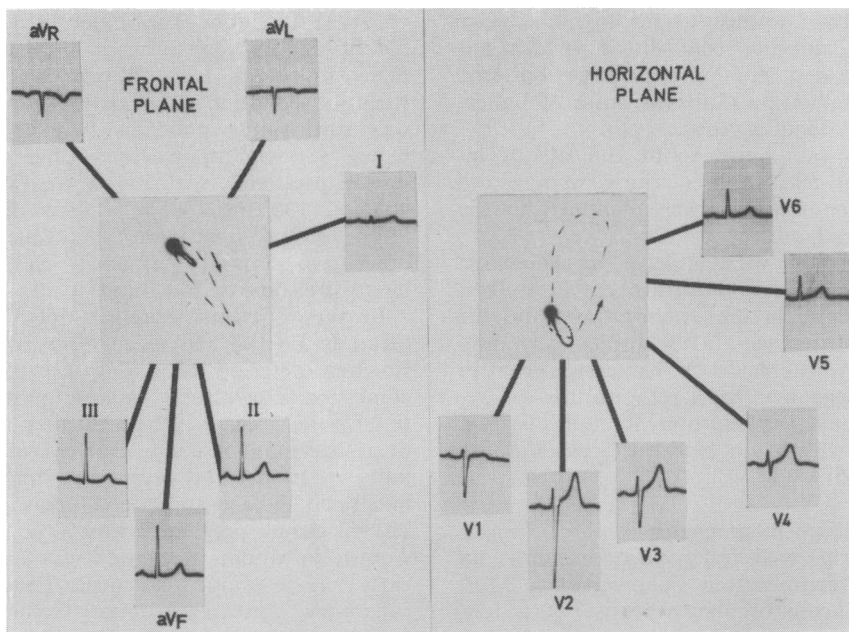
Acknowledgments

Fig. 11. Scalar records mounted along the lead axes of a corrected twelve-lead spatial reference system based on Burger's scalene triangle.

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Renal disease in pregnancy

K. F. FAIRLEY

*Royal Women's Hospital,
Melbourne*

PRISCILLA KINCAID-SMITH

*Queen Victoria Hospital,
Melbourne*

SURPRISINGLY, little data is available about the maternal and foetal prognosis when pregnancy is complicated by renal disease.

Over the past 8 years we have studied various aspects of renal disease in pregnancy and our findings are summarized below.

Renal infection in pregnancy

This is certainly the commonest form of renal disease in pregnancy. Frank pyelonephritis of pregnancy occurs in about 1% of women and in over 30% of women who show over 100,000 organisms/ml in a urine specimen collected at their first antenatal visit (Kincaid-Smith, 1965; Kincaid-Smith & Bullen, 1965). About two-thirds of all cases of pyelonephritis of pregnancy can be prevented by treatment of asymptomatic bacteriuria (Kincaid-Smith & Bullen, 1965).

The incidence of asymptomatic bacteriuria varies from 4 to 15% in various parts of the world (Kass, 1960; Kincaid-Smith & Bullen, 1965; Le Blanc & McGanity, 1965; Stuart, Cummins & Chin, 1965; Little, 1967). The complications of pregnancy bacteriuria also vary in different series. We related the high incidence of prematurity, foetal loss and pre-eclamptic toxae-