opportune for him to share with us some findings from his excellent study and to present his thoughts regarding the etiology of congenital heart diseases, which are in almost complete agreement with our own. I do believe that our experience and thinking about the etiology of congenital heart diseases has progressed considerably beyond the referenced 1968 article (references 3–5). In the paper under discussion, we carefully avoided an exploration of etiologic issues, preferring, as Dr. Zetterqvist knows from our conversation, to reserve this for detailed presentation in a monograph which we are preparing on the subject. We had only one very limited objective for our article: to make empiric recurrence risk figures available in an accessible place.

References

Toward Standardized VCG Systems

To the Editor:

A certain degree of worldwide uniformity has been achieved in conventions, terminology and definitions of the conventional 12-lead electrocardiograph (EKG). In contrast, a nearly chaotic state prevails in vectorcardiographic (VCG) recording and reporting. A large number of VCG lead systems have been developed and several of these have found acceptance in clinical or research applications. However, the existence of a variety of different VCG lead systems is not the sole culprit. Over the course of many years of professional involvement in research and practical application of VCG methodology, I have become aware of the potentially harmful consequences of indiscriminate modifications of the original design of VCG lead systems. Substantial deviations from the design specifications of the original authors have been introduced, particularly in the application of the McFee-Parungauo and the Frank lead systems.*

The Frank lead system has become the most widely used VCG lead system. The widespread acceptance of the Frank lead system has, in essence, introduced a potentially universal standard to VCG reporting. Regrettably, the many modifications introduced into clinical practice have virtually blocked these gains toward uniformity. Of particular concern to VCG investigators is the placement of the precordial X and Z lead electrodes, variations in which result in unacceptably large discrepancies among medical centers. A VCG, labelled as 'Frank lead VCG,' may variously refer to a record made with precordial electrodes placed either at the fourth intercostal space at the sternal border or at the level of the fifth intercostal space at the midclavicular line. These two levels may be far apart and in some patients the discrepancy in the horizontal level of the X and Z lead electrodes may amount to more than 6 cm.

Frank designed his lead system to achieve a high degree of orthogonality on the basis of the properties of one particular image surface determined for a specific dipole location at the level of the fifth intercostal space at sternum. In the appendix of the article in which Frank originally described his lead system, he proposed a three-step procedure to identify the vertical level of the equivalent dipole for ventricular depolarization,4 the level at which the X and Z lead electrodes should be located. The proposed procedure is relatively cumbersome, and furthermore, the results from our laboratory indicate that the validity of the method can be questioned. As a practical compromise, Frank suggested that the fifth interspace at sternal level be used for clinical practice.

Proposals for modifications of VCG lead systems are often based on intuition, casual comments, or anecdotal evidence rather than on scientific facts. It is evident that VCG investigators have not been critical enough in the past to carefully evaluate the evidence offered to justify the modifications proposed. For instance, there is no conclusive evidence to support the assertion that, in supine subjects, the vertical level of the "equivalent dipole" of ventricular depolarization shifts to the level of the fourth interspace.

Accepting the assertion that the anatomical center of ventricular mass can be taken as an approximate location of the "equivalent dipole,"5 the report of Kaneko et al.6 provides some interesting data. Vertical variation of the location of the anatomical center of the heart is quite large, with a 96% range extending from about 4 cm above the fourth to 14 cm below the sternal border. In the group of 106 supine patients reported by Kaneko et al., the median of the vertical distribution of the center of gravity of the posterior-anterior X-ray projection of the heart coincided with the level of the fifth intercostal space at sternum (fig. 2, Am Heart J 74: 60, 1967). In 95% of these supine patients, the anatomical center of the heart was below the fourth intercostal space.

Recent results of Riekkinen and Rautaharju6 indicated a highly significant decrease in the R and Q wave amplitudes in leads X and Z and in the maximum spatial magnitude of QRS when the horizontal level electrodes were shifted from the fifth to the fourth interspace, resulting in substantial changes in diagnostic interpretation in 12.5% of the patients studied. In summary, it appears that the modification of the Frank lead system by shifting the X and Z lead electrodes one interspace higher than specified by Frank was done too hastily, without an adequate investigation to justify this substantial deviation from the original design specifications.

This objection is valid for other modifications of the Frank lead system. Of particular concern are those modifications which permit the placement of one or more of the precordial electrodes at a level which is different from that of the rest of the X and Z lead electrodes. Problems can be compounded by modifications which permit a further transverse deviation of some of the electrode placements (e.g., electrode C).

It is evident that in the past we have not been careful enough in evaluating deviations from original specifications. In retrospect, it seems that there is adequate justification to recommend that a VCG lead system should be used exactly as specified by the original author. When valid reasons for modifications are proposed, data should be developed to verify that the modified system is compatible with the original design, or that any differences in VCG measurements are less than the inherent repeat variation. The burden of proof is in the hands of the investigator who proposes a modification. Adequate statistics of measurements made with representative groups of normals and patients in various disease categories should be provided.

When significant systematic differences are observed, a correction should be introduced in the lead network, or in computation, to produce measurements which match as closely as possible the signals as recorded by the original lead system. If this is not possible, and the requirements for a modification still persist, the particular lead or lead system should be given a new name. "Modified Frank lead" has become a confusing label. 'Modifications of modifications' are likely to lead to disorder.

The consequences of illegitimate VCG lead system modifications can be very costly. Many years of effort are easily consumed by the assessment of the effect of lead system modifications and deviations from original specifications. Through adherence to the original

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specifications this unnecessary effort can be avoided and invested more profitably in attempts to enhance the diagnostic power of VCG and to enter other areas of VCG research.

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