If the complex function of the cardiovascular system has to be analysed - for a better understanding of its normal behaviour and the various disease states - a number of methods is available, such as electrocardiography, phonocardiography, oximetry, echocardiography and heart catheterization procedures, which offer specific aspects of the overall activity of the circulatory system.

Radiological techniques are extremely valuable - and in many cases indispensable - since they allow the analysis of structure and function of the cardiovascular system in particular, if the blood is marked by a radioopaque "indicator" or contrast agent. The resulting angiographic images display the information in a way which is extremely suitable to a subjective, visual perception.

Cine- and Videoangiography allow the recording of the central or regional blood flow and its distribution as well as the dynamic changes of the size and shape of the heart chambers.

When we started to apply these techniques in clinical routine for diagnostic purposes (1964), it became clear very soon, that there was much more information in an angiographic image series than was conventionally extracted and used just by observing the passage of the contrast medium.

It is the purpose of this article to trace the way from conventional angiocardiography to quantitative angiocardiometry and to review the evolution of digital cardiovascular radiology based on some ten years of own experience and developments in our interdisciplinary group. The techniques for computerized tomography or dynamic spatial reconstruction of the heart (DSR) (43) are not discussed in this paper.

The initial motivation for our efforts was rather simple, namely:

a) to improve conventional cardiovascular radiology for the benefit of the patient, and

b) the belief, that this could - at least in part - be achieved by quantitation of the angiographic image (series) information, i.e. by extracting numbers and parameters from these images, which characterize the structure and function of the cardiovascular system.
From the known biological and pathophysiological concepts of the cardiovascular function it could be expected, that the determination of the quantity and direction of central and regional blood flow or intracardiac shunts as well as morphological parameters - such as size, shape and contraction of the heart chambers - would give more insight into the mechanisms and severity of cardiovascular diseases. This in turn should not only improve the accuracy and reliability of the diagnosis and prognosis but also the therapeutic concepts and decisions (e.g. operability etc).

There are two separate ways to quantitate all kinds of angiocardiographic images or image series, which do not necessarily require digital techniques:

a) the measurement of local densities and their temporal changes

b) the measurement of single or multiple diameters, distances or areas, characterizing various cardiovascular structures.

Starting with cine densitometry in 1964 we soon adopted a method - originally developed in the Mayo Clinic by Wood et al. (42), called VIDEODENSITOMETRY, which had the advantage of straightforward electronic signal processing. For quantitative videodensitometry however the basic requirements were not yet fulfilled at that time. Extensive studies on the usefulness and limitations of conventional x-ray equipments for quantitative measurements (17) and the applicability of Lambert-Beer's law to x-ray absorption by contrast material provided the basis fruitful experimental and clinical application (2-4, 17).

Videosignal processing was at that time exclusively by analog means - but computerized evaluation of the videodensitometric output signal was soon introduced and the programs have been adapted to the specific requirements of the radio-opaque dilution curves. Videodensitometry became thus the first occasion to connect the x-ray video chain to a digital computer.

The method proved to be very useful for quantitative flow measurements in different parts of the circulation, determination of cardiac output, determination of cardiac shunts and in particular for quantitation of valvular incompetence (3, 4, 17, 20, 21, 36-39).

With the rapid progress in electronic technology it became possible to select from the videoimage manually or (semi)automatically defined contours of the cardiovascular silhouette and to transfer these digitized ventricular border coordinates into a computer in real time (18).