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Pediatric echocardiographic nomograms: What has been done and what still needs to be done

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ABSTRACT

Nomograms are essential tools for quantification in pediatric echocardiography. In the last few years, multiple sources highlight that nomograms employed for decades presented significant numerical and methodological limitations. As a result, widely different ranges of normality were generated, thus creating confusion in estimation of several cardiac diseases. New nomograms have recently been generated, overcoming some of the gaps of previous research: wider sample sizes (including neonates/infants), solid statistical/methodological plan, and availability of new data (chamber dimensions, many functional parameters). In particular, robust two-dimensional nomograms covering a wide spectrum of cardiac measurements have recently become available. Significant advances have been made for functional data (i.e. diastolic and deformation indexes) but a few limitations still exist. These include numerical issues (sample size of below 400 subjects) and methodological pitfalls (heterogeneous data normalization/expression). Despite these limitations, however, actual nomograms for functional data present quite reproducible intervals of normality with the exception of neonates and infants.

In conclusion, great advances have been made during the last years. A few basic rules for the building of nomograms have been established (i.e. inclusion/exclusion criteria, measurement standardization), while others (i.e. the sample size, the way to express/normalize data, statistical requirements) are basically defined but still require standardization. New pediatric echocardiographic nomograms of good quality are easily accessible due to new electronic tools (online calculators, apps for smart-phone/tablets). Studies are ongoing to generate wider, comprehensive and multi-ethnic nomograms and to evaluate new parameters (e.g. three-dimensional parameters).

Key words: Echocardiography, Children, Neonates, Nomograms.

Introduction

Echocardiography is the first bed-side imaging modality for diagnosis of congenital heart disease (CHD) and nomograms are essential tools for quantification and CHD severity estimation in children [1]. In the last few years, various authors observed how nomograms, used from the late 1990s, had several numerical and interpretative limitations [1–8]. Indeed,

List of abbreviations: BSA, body surface area; CHD, congenital heart disease; e', peak myocardial velocity at the lateral mitral annulus in early diastole; IVC, inferior vena cava; MRI, magnetic resonance imaging; RV, right ventricle; RVOTSE, right ventricular outflow tract systolic excursion; s', tricuspid septal tissue Doppler systolic velocity; TAPSE, tricuspid annular plane systolic excursion; S`, tricuspid annular peak systolic velocity; 3D, three dimensional echocardiography.

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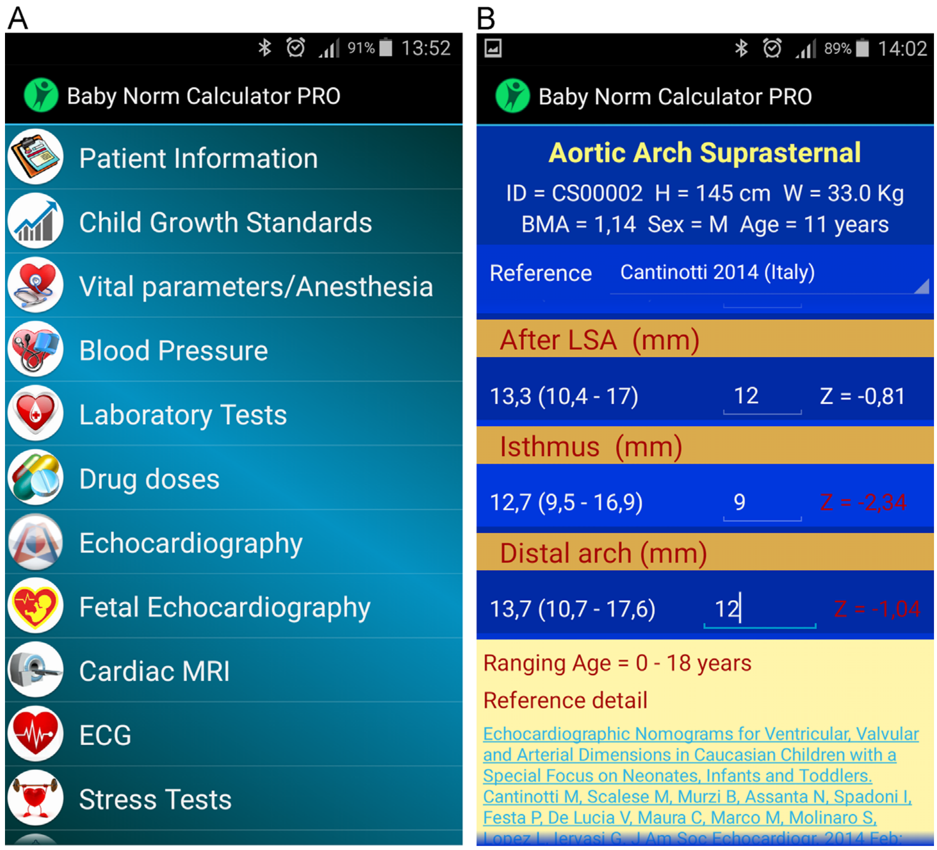

Fig. 1 – A and B: examples of screen-shots of BabyNorm, an app for smart-phone developed for automatic pediatric echocardiographic z score calculation.

different published nomograms created considerably discordant Z scores for a given measurement [1–8], thus generating confusion in grading the severity of a CHD. This evidence opened a great debate on the need for new and more reliable pediatric echocardiographic nomograms. Awareness of the problem led to approaches to overcome the numerical and methodological limitations inherent in current nomograms. Studies to establish more robust and accurate pediatric nomograms are ongoing, in North America, Europe, and Asia [5,9–73] and new pediatric normative data have been proposed. New nomograms present significant advances over previous research, particularly those for two-dimensional measurements. Normative data on functional indexes continue to be fraught with multiple limitations. Some basic concepts for the building of nomograms with a sufficient accuracy have been established [1,5,6]. For instance, it is widely accepted that echocardiographic parameters should be normalized for BSA and data expressed as Z scores [6]. However, a few concepts remain undefined and the statistical power of some nomograms, particularly those pertaining to functional indexes, continues to be weak. Various authors have still adopted the limited sample sizes and z score equations have been built despite the fact that the relationship of parameters used for normalization (i.e. body surface area, age) with echocardiographic parameters were weak (i.e. coefficient of relation <0.03) [61,62]. This introduces a significant bias when these results are translated into a clinical aspect.

The aim of the present work is to provide a State of the Art Review of currently available nomograms and a new prospective on upcoming pediatric echocardiographic nomograms including anatomical and functional parameters (Fig. 1).

General aspects: how to build a pediatric echocardiographic nomogram

How to perform measurements

When building a pediatric echocardiographic nomogram, a series of issues need to be faced [1–10]. Firstly, it is important to decide how to perform the respective measurements [1,3,4,9,10]. In the past, there was sometimes confusion on how some measurements should be performed and various times of the cardiac cycle often have been employed [3,4]. Recommendations for quantification during the performance of pediatric two-dimensional echocardiography have been published a few years ago (i.e. 2010) [1]. However, a standardized methodology to measure blood flow, tissue Doppler velocities, as well as strain velocities and strain rate is not available to date [4]. Thus, different echocardiographic views to perform dimensional measurements, and different myocardial segments to evaluate functional/deformation indexes continue to be employed even in more recent works [4]. For