Estimation of Ejection Fraction with Ventriculography Versus Echocardiography in Patients Referred for Cardiac Surgery

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Abstract: *Aim*: The aim of this study was to compare the estimation of ejection fraction (EF) by ventricuography (VG) and echocardiography (ECHO) in patients referred for surgery and to validate the results by comparison with other published data.

Methods: One hundred patients who underwent VG prior to surgery were subjected to a trans-thoracic ECHO. Radiographers calculated the EF by tracing the outer border of the ventriculogram during systole and diastole. A single cardiologist, who was blinded to the angiogram result, measured EF during trans-thoracic ECHO using the biplane Simpson's method.

Results: EF was significantly higher by VG versus ECHO for the whole group (67.9±13.2 vs 55.7±8.5, p=0.000). In 81 patients the EF estimated at VG was higher than that calculated at ECHO (71.7±10.2 vs 55.9±7.2, p=0.000). In 19 patients the EF estimated at VG was lower than that calculated at ECHO, but the difference was not significant (51.8±12.9 by VG vs 55.4±12.8, p=0.387). In 13 patients, with an EF less than 50% on VG, the correlation with ECHO was very good (42.0±9.0 vs 42.0±8.3, p=0.995). Two patients with an EF fraction under 30% had similar measurements by VG and ECHO. The EF range as measured by ECHO was consistent with published data.

Conclusion: Ventriculography overestimates EF when compared with ECHO. When EF is less than 50% on VG, ECHO findings were similar. The value of ventriculography in patients referred for cardiac surgery is now being brought into question when ECHO, a better and less invasive test that measures EF, is available.

Keywords: Ejection fraction, ventriculography, echocardiography, cardiac surgery.

INTRODUCTION

Ejection fraction is readily measured invasively at ventriculography and non-invasively by echocardiography. A value of around 65% is considered normal [1]. Ejection fraction contributes to pre-operative risk assessment when using the Parsonnet or EuroSCORE systems.

The calculation of EF and assessment of regional wall motion by contrast injection of the left ventricle has been a gold standard for over four decades [2] since its introduction by Seldinger in 1953 [3]. The increasing use of VG sparked concerns over radiation exposure [4] and brought its validity into question, especially when patients had already undergone echocardiographic estimation of ventricular function [5,6]. Surveys have highlighted a wide divergence of its use, with the suggestion that reimbursement by private health schemes may be a driving force [7].

This is not an issue in our local public-funded Health Service. Although our resident surgeons, comfortable with ventriculography, initially expressed reluctance to embrace echocardiography, the strong drive to change eventually arose both from within our surgical fraternity as well as from cardiologists.

Factors included the divergence of EF estimation between that calculated by radiographers and that visually estimated by surgeons, the elevated range of EF calculated locally by ventriculography, far exceeding internationally expected norms [8,9] resulting in an underestimation of operative risk, the increasing appointment of non-invasive cardiologists providing an ECHO service, and the increasing reluctance of invasive cardiologists to perform ventriculography.

Against this background we evaluated our changing practice in order to define the place of invasive versus non-invasive EF estimation in patients referred for surgery.

METHODS

One hundred patients who were referred for a cardiac surgical procedure and had undergone VG were subjected to a trans-thoracic ECHO. The history excluded an interval episode and the ECHO was performed soon after the VG.

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Patients who were considered possible candidates for surgery were first screened in order to ascertain the need for invasive investigation. Ventriculography was always performed as part of the coronary angiogram and invasive pressure measurements. The interventional cardiologist established that the patient had reached a steady cardiovascular state before injecting contrast. Radiographers traced the outer border of the ventriculogram during systole and diastole (two dimensional area), and entered this data to compute the ejection fraction by standard methods using derived systolic and diastolic volumes [10].

A single cardiologist, blinded to the VG results, estimated the EF on trans-thoracic ECHO, using the biplane Simpson's method [11]. Other parameters relating to valvular function, regional wall motion and areas of interest relevant to the patient's specific heart disease were recorded during this echocardiogram. Measurements were taken when the patients reached a steady state at rest.

Ejection fraction was expressed as a percentage of stroke volume divided by end-diastolic volume.

Means and standard deviations were used to measure central tendency and dispersion for continuous variables and the unpaired t-test was used to compare mean EF calculated by VG and ECHO modalities, given that both variables satisfied the normality assumption. A 0.05 level of significance was adopted in all comparisons.

RESULTS

Seventy-three patients were male and mean age for the whole group was 65.7±9.6 years (males 63.5±9.6, females 71.4±7.1). All patients underwent surgery with the following procedures: 55 coronary artery bypass grafting, 12 aortic valve replacement, 10 aortic valve replacement with concomitant grafting, 10 mitral valve repair, 8 mitral valve replacement and 5 other miscellaneous procedures. The time interval between the two tests was 25.8±20.8 days. The absence of any intervening episode from the measurement of VG was ascertained at the time of ECHO.

EF was significantly higher by VG versus ECHO for the whole group (67.9±13.2 vs 55.7±8.5, p=0.000) Figure **1**.

In 81 patients the EF estimated at VG was higher than that calculated at ECHO (71.7±10.2 vs 55.9±7.2, p=0.000). In 19 patients the EF estimated at VG was lower than that calculated at ECHO, but the difference was not significant (51.8±12.9 by VG vs 55.4±12.8, p=0.387) Figure **2**.

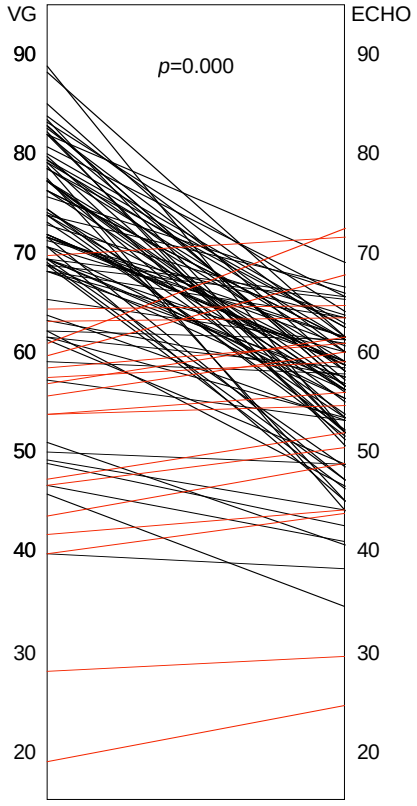

Figure 1: Black lines EF by VG > EF by ECHO. Red lines EF by VG < EF by ECHO.

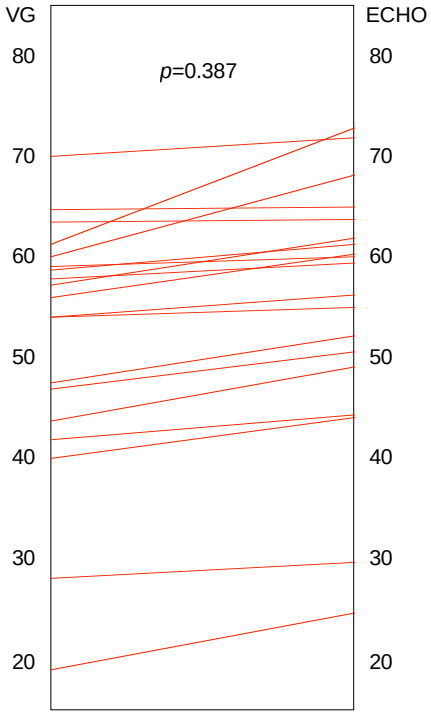

Figure 2: Red lines EF by VG < EF by ECHO.

In patients with an EF less than 50% on VG (n=13), ECHO estimations were similar (42.0±9.0 vs 42.0±8.3, *p*=0.995) Figure **3**.

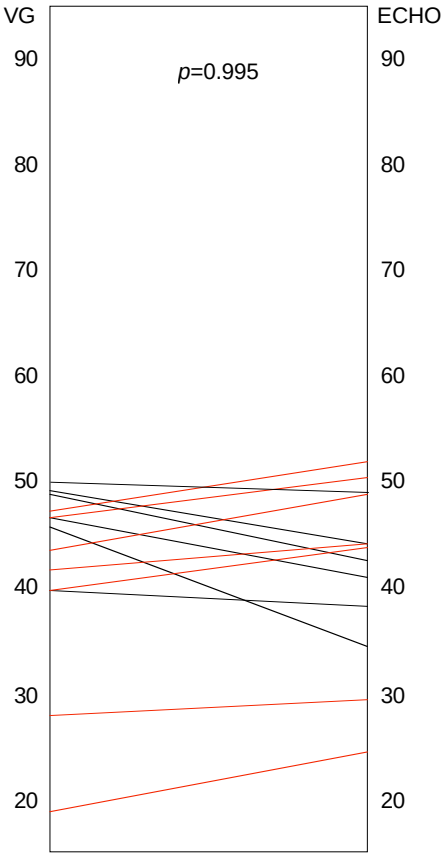

Figure 3: EF by VG < 50%, red lines EF by VG < EF by ECHO.

Two patients with an EF fraction under 30% had similar measurements by VG and ECHO.

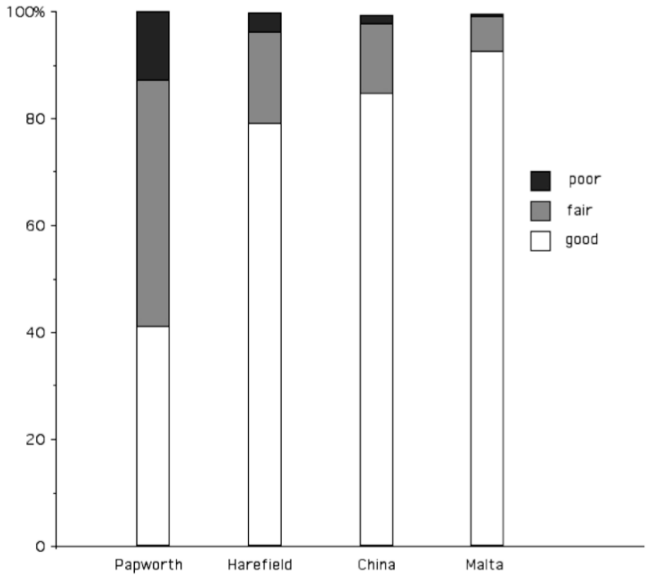

Figure 4: Percentage distribution of EF: poor < 30%, fair 30-50%, good >50%.

The range of EF was compared with internationally published data, both from Europe and from China (Figure **4**) [8,9].

The proportion of local patients deemed to have a poor or fair left ventricular function as measured by VG during the period 2001-2012 was much lower than in other contemporaneous series (Malta 2001-2012, UK 2001-2008, China 2006-2008).

DISCUSSION

The trend internationally is for an increase in non-invasive at the cost of invasive investigation. This applies both for the assessment of EF [12] as well as for estimation of the significance of coronary lesions in ischaemia [13,14]. Ejection fraction is not the sole test for evaluating heart function, and diastolic dysfunction, easily assessed by ECHO, is gaining increasing importance [15].

Several technical pitfalls may affect EF estimation on VG. The formula constant may require calibration in relation to other methods of measurement, such as ECHO or radionuclide ventriculography. Inaccurate tracing of the ventricular cavity and filling defects caused by papillary muscles, especially with left ventricular hypertrophy may underestimate end-systolic volume. A high position of the catheter within the ventricle, or inadequate contrast volume and rate of injection, especially with smaller catheters, both fail to delineate the entire cavity adequately. Measurements taken during ventricular ectopics or salvos, caused by the catheter or the injection, or after a compensatory pause, are not representative because of the influence on ventricular filling. A left ventricular aneurysm may not be adequately filled, underestimating the true dimensions. Similarly, poor windows or indefinite endocardial border definition may hinder ECHO measurements. Ventricular aneurysm invalidates EF estimation using formulae based on a normal ventricular contour [16]. Finally there may be variations in the way different cardiologists perform the ventriculogram and also in the delineation of ventricular contours by various radiographers.

The EF range as measured locally by VG was vastly higher than other published data [9]. These ranges were for patients referred for cardiac surgery contemporaneously (Malta n=1649, 2001-2012, Harefield n=4408, Papworth n=8862, 2001-2008, China n=8774, 2006-2008). Our local EF for this specified cohort was 71.8±13.6 versus a normally quoted range

of 62.3±6.1 [17]. Overestimation of EF by VG has been described previously [18].

Ejection fraction affects predicted outcome in widely used surgical risk-stratification systems, with increments at EF <50% and <30% [19-21]. Eleven patients in our study, with an EF >50% by VG would have been reclassified as <50% by ECHO, with a consequent increase in risk-stratification score (Figure **5**).

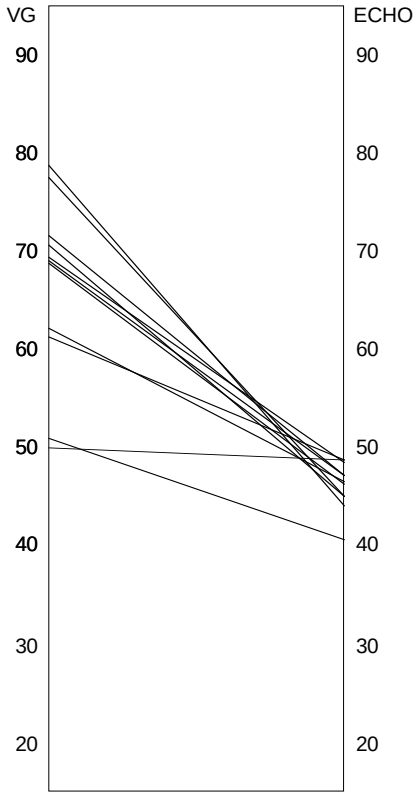

Figure 5: EF > 50% by VG and < 50% by ECHO.

Figure **6** shows the local trend for the use of ECHO for EF estimation over time.

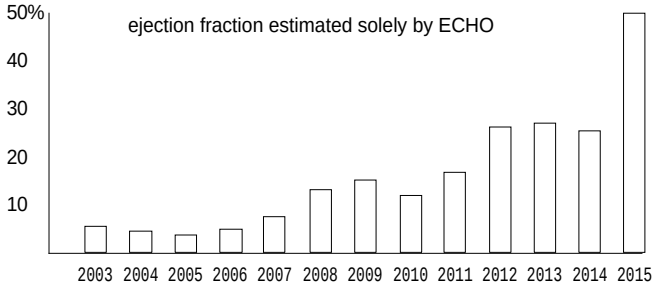

Figure 6: Use of ECHO for EF estimation over time.

LIMITATIONS

Ejection fraction is one of many contributory factors in the estimation of operative risk and outcome. The emergence of newer risk stratification systems designed to deal with a changing surgical population makes the correlation between EF and outcomes difficult to accurately quantify. This study did not address outcomes in terms of EF by VG or ECHO. Locally acquired VG estimates were higher when compared with those reported in other registries, and hence the applicability or interpretation of these findings may be limited.

CONCLUSION

The pursuit of a gold standard in EF estimation is a concept largely subordinated by the local availability of techniques and practices. Each modality possesses its strengths and weaknesses and should be tailored to clinical need when patients are referred for surgery. Ventriculography overestimates EF when compared with ECHO and surgeons are cognizant of this shortcoming. When EF is less than 50% on VG, estimation by ECHO is similar. The value of ventriculography in patients referred for cardiac surgery is now being brought into question when ECHO, a better and less invasive test that measures EF, is available. The trend from VG to ECHO in our unit reflects these complex dynamics and has emerged for an increased use of ECHO as the sole method of EF estimation in patients referred for surgery. It behooves the surgeon to become increasingly acquainted with this modality as VG becomes less accessible.

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