

Utility of the Effective Regurgitant Orifice for the Quantification of Regurgitant Valve Lesions

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A recurring task in the work of a clinical cardiologist is to quantify the degree of mitral regurgitation in patients with valvular incompetence. Its relevance in establishing surgical indications^{1,2} and providing a prognosis for patients with several types of cardiovascular disease^{3,4} makes the attempt to improve the measurement of regurgitant flow in these patients essential. Several clinical signs and invasive/noninvasive methods have recently been used to this end.⁵

The introduction of Doppler color flow mapping several years ago enabled the visualization of cardiac flow. The different types of flow found in the cardiac cavities—normal anterograde flow, shunting, and regurgitant jets—have different characteristics. From this perspective, studying regurgitant jets has obvious diagnostic and prognostic relevance. However, hopes that it would be relatively simple to measure regurgitant lesions⁶ with this technique soon proved false. All the methods used to measure the severity of valvular regurgitation by measuring the jet or attempts at reconstructing the jet from several planes have proven difficult.⁷ It is now clear that the appearance of turbulent jets depends on factors different from regurgitant flow, while the influence of instrument settings, driving pressure and so-called wall jets is well known.⁸ From the point of view of hydrodynamics they have intrinsically different magnitudes because the regurgitant jet includes extra

fluid belonging to the receptor chamber and the amount depends on the driving pressure for a given regurgitant volume.

In any case, the clinical use of semiquantitative measurements of regurgitant flow—which enable analyzing the jet, even by simple visual estimation—is undeniably useful and can be validly compared to far more refined methods.^{9,10} Thus, it continues to be the most commonly used method in our setting, not only for the rapid measurement of valvular regurgitation, but also for prognosis by using both the measurement of the jet's dimensions and the visual estimation mentioned, where the operator combines a series of already known data into the evaluation process.

On the other hand, theoretical work on fluid behavior and the need for a quantitative approach (more comprehensive and reliable measurements) have led to the study of two new methods for measuring regurgitant flow: momentum analysis and flow convergence.^{11,12} Both techniques enable calculating maximum flow, regurgitant flow/beat, and regurgitant flow. It must be mentioned again that, in all these cases, the calculations not only reflect the severity of valvular regurgitation, but also the patient's current hemodynamic situation, which can vary.

Momentum is the physical parameter that provides the best description of jet patterns.⁹ Two methods have been used to calculate this. The first⁸ uses the property of dynamic similarity of the jet. This method involves intrinsic difficulties in practice, the first of which, breathing, can be overcome; second, there is the phenomenon of intrinsic flows that impinge on the measurement area; and, third, there are also practical difficulties involved in aligning the Doppler beam with the central jet, which is hindered by cardiac motion and turbulence. The calculation of U_m (central velocity of the jet) seems even more difficult to solve and, in the case of wall jets—which are involved in a considerable number of patients—early transfer of momentum before it is fully developed makes it unquantifiable.

The second method for quantifying momentum—where the information on velocity coded in the pixels has a proportional weight, in contrast to the binary

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system—calculates momentum as $M = 2\pi\phi r u(r)^2 dr$, where u is the mean velocity and r the perpendicular distance of a point to the center of the jet. However, this theoretically sound method has several problems regarding its application, such as analyzing the coordinates of all the pixels, the poor lateral, temporal and spatial resolution of the equipment available, and the lack of definition around the aliasing area.

Given the above, we arrive at a quantitative method that can be currently applied in the clinical context to any type of jet and that does not need additional technology. On the other hand, in 2003, the American Society of Echocardiography published new recommendations for estimating the severity of valvular lesions using bidimensional echocardiography and Doppler ultrasound, which was included as a useful parameter for evaluating mitral regurgitation. The principle underlying the phenomenon of proximal acceleration^{12,13} is found in any fluid dynamics textbook, i.e., that flow approaches a specific orifice in a flat surface as a series of hemispherical isolines with a progressively smaller surface and progressively greater velocity. In these circumstances, and by applying the principle of conservation of mass, the instantaneous flow through the orifice can be calculated as the product of the velocity of one of these isolines multiplied by its surface area. Based on this, the concept of regurgitant orifice was introduced in the 1990s^{14,15} from which, similar to what occurred regarding valvular stenosis, the magnitude of the regurgitant valve lesion can be calculated relatively independently of the hemodynamic situation. This interesting idea has clear clinical and surgical implications and continues to be of undeniable conceptual value, leading to useful contributions and new approaches to calculation and follow-up.¹⁶ Its measurement is simple and has excellent correlation with the regurgitation fraction, both in the mitral and tricuspid valves, and is also demonstrably more stable than volume measurements regarding clinical follow-up.¹⁵

However, there are problems inherent to the method for calculating the regurgitant orifice, for example, the local geometry of the valve, which in many cases, is different from the shape described by the theory of convergent flow. In this context, a surface with a distorted base is encountered rather than a flat surface; this affects the outcome and would require a change in the constant 2π in order to describe the surface angle. Another problem that should be borne in mind is that, in the original theoretical models, viscosity was not taken into account; however, we know that blood has a finite viscosity that can lead to the formation of marginal strata that can distort the hemispherical morphology of the isovelocity lines. Although it is accepted that convergent flow area is barely affected

by the echocardiography device settings, if we compare it with the turbulent regurgitation area, a distorting effect has been reported leading to using a low impulse repetition rate that tends to underestimate the calculated flow. Currently, it is also known that lowering the aliasing line of the high frequency wall filters makes the low velocities of the coded map disappear and overestimates the velocities represented on the map. Even so, and after assessing all these factors—some of which are compensated for when obtaining the result—it has been proven that the method works successfully when compared with the other methods available.

Moya et al¹⁷ have broad and successful experience in the study and use of the proximal acceleration method applied to mitral valve regurgitation. In this issue of the *REVISTA ESPAÑOLA DE CARDIOLOGÍA*, they address an aspect that possibly leads to this type of analysis being underused in clinical practice, i.e., it is thought to be difficult to perform. Although most Doppler ultrasound equipment includes the software needed to simply and rapidly calculate flow, many echocardiography specialists have been slow to adopt this, thus hindering the widespread use we consider it deserves. Thus, the authors, leaving aside its intrinsic quantitative potential, have used it semiquantitatively, proved its clinical usefulness and reliability and, in addition (which makes it especially interesting), obtained considerable time savings. As they mention, their method fulfills the recommendations of the European and American cardiology societies.

Efforts such as those made by Moya et al¹⁷ are welcome and should be supported by this method becoming more widely used. It has effectively proven its worth in all the theoretical and practical tests it has been submitted to, although it has not yet achieved the popular success it deserves.

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