ERRORS IN TRANSRECTAL ULTRASONIC PLANIMETRY OF THE PROSTATE: COMPUTER SIMULATION OF VOLUMETRIC ERRORS APPLIED TO A SCREENING POPULATION: REGARDING BANGMA ET AL. UMB 21(1):11-16; 1995

To the Editor-in-Chief:

With interest we’ve read the contribution by Bangma et al. in Ultrasound in Medicine and Biology 21(1) about the errors in transrectal ultrasonic planimetry of the prostate. It is an interesting study towards the errors introduced in a clinical application of numerical integration, in the case of prostatic volumetry. However, we would like to make some comments to their investigations, results, and the conclusions.

The authors examined the influence of three errors in this volumetry: the salami effect, the capsizing effect, and the first step effect using a computer simulation. The errors of the three effects were assessed with computer simulations using ellipsoid-shaped objects with varying length, height, and width. The volumes of the objects obtained with planimetry were compared to the exact ellipsoid volume. The authors kept the most important parameter in numerical integration, the intersection distance, fixed on 5 mm.

An interesting investigation is presented concerning the salami effect introduced when the transverse sections are not perpendicular to the longitudinal axis of the geometrical body. The authors are right when they state that this effect may lead to different surfaces and might even influence the number of cross-sections. As long as the probe is retracted along its own axis, the thickness of the slices is not influenced by this effect, as can be seen from Fig. 2 in their article.

They also conclude that the salami effect in planimetry is mainly dependent on the length of the ellipsoid, while in caliper measurements this angulation effect depends on the angle α. However, in planimetry the effective length of the ellipsoid is dependent on the angle α as well; the effective length is the distance between the two tangential planes at the apex and base of the ‘prostate.’ This distance between the tangential planes is depending on the angle α and the shape of the prostate. When the prostate length is larger than the prostate height, as normally seen in the clinic, the effective length of the prostate under angulation will always be smaller than the actual length. Therefore, the number of cross-sections taken under angulation will always be equal or smaller than expected from the actual prostate length. On the other hand, for prostates with a larger height than length, the angulation effect may be advantageous, since a larger effective length can be obtained and, therefore, a larger number of cross-sections may be taken from the same object.

From the computer analysis, it was concluded that the errors of the salami effect and the capsizing effect were larger for shorter ellipsoids. However, not only the salami and capsizing effect is measured in this case, but also the effect of the intersection distance. For theoretical analyses it makes no difference whether you reduce the length of the object or increase the intersection distance with the same proportion. Not the intersection distance itself, but the intersection distance relative to the length of the object to be integrated is important for numerical integration. When no other parameters are changed during numerical integration, like the selection of the first section, the errors obtained in an ellipsoid of 50-mm sliced with 5-mm are the same as for an ellipsoid of 40-mm sliced with 4-mm intersection distance. This means that not the salami or capsizing effect, but the fact that less cross-sections are used to determine the volumetry can thus be described by

\[ \frac{x}{a} \left( \sqrt{1 - \left( \frac{z}{c} \right)^2} \right) + \frac{y}{b} \left( \sqrt{1 - \left( \frac{z}{c} \right)^2} \right) = 1 \]

with a prostate width \(2a\), height \(2b\), and length \(2c\).

Cross-sections in the plane \(z = z_0\), perpendicular to the \(z\) axis can be described by

\[ \frac{x}{a} \left( \sqrt{1 - \left( \frac{z_0}{c} \right)^2} \right)^2 + \frac{y}{b} \left( \sqrt{1 - \left( \frac{z_0}{c} \right)^2} \right)^2 = 1 \]

The area of these cross-sections used to obtain the planimetric volume can thus be described by \(\pi \times a \times b \times (1 - (z_0/c)^2)\) and thus linearly related to the height and width of the prostate. The sum of a discrete number of areas obtained with fixed distance is, therefore, also related to the height and width. The relative error is obtained by dividing the numerical volume by the exact analytical volume:

\[ \frac{\sum \pi \times a \times b \times (1 - \left( \frac{z}{c} \right)^2)}{\frac{\pi \times a \times b \times c}{6}} = \frac{\Sigma \left(1 - \left( \frac{z}{c} \right)^2\right)}{\frac{c}{6}} \]

This expression for the relative error shows that not the width or height but the length of the prostate is the determining factor. Again, the error is produced by the fact that less cross-sections are used.

In conclusion, because the assessment of the influences of the salami, capsizing and first-step effect are combined with, a varying prostate length, it is hard to extract the influences of each effect individually. Indeed, the effects are
summarized in a practical application and the article gives a good overview of the errors to be expected in prostatic volumetry with 5-mm intersection distance. However, how prostatic volumetry can be improved by reducing one of the effects cannot be extracted from the article. This is also reflected in the conclusions where the authors state that to minimize these effects introduced by the three effects the caliper length should be compared to the number of cross-sections. In our opinion, this is a cryptical description for a recommendation to use a fixed number of cross-sections instead of a fixed intersection distance. However, this is not the solution to overcome the influences of one of the effects. Also, the introduction of a critical area to define the first section of the volumetry does not overcome the errors of the first-step effect. Since the last section is still arbitrary depending on the length of the prostate, the volumetry will not be more accurate, it will only be more reproducible using a fixed starting point.

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IN RESPONSE TO DR. AARNINK AND WIJKSTRA

To the Editor-in-Chief:

In our article concerning errors in transrectal ultrasonic volumetry of the prostate, we have used a computer model to simulate possible factors leading to inaccuracy of planimetric measurements in vivo. The prostate simulation was based on simple formulas describing ellipsoids, as mentioned by Drs. Aarnink and Wijkstra. This is extensively illustrated in the thesis "Prostate specific antigen and ultrasonography in detection and follow-up of prostate carcinoma," which will be published at the Erasmus University Rotterdam in December 1995.

We have chosen to perform a computer simulation, because the rotation along the x axis in combination with movements along the z axis render an exact analytical error calculation of a great variety of ellipsoids nearly impossible.

The article reflects the magnitude of certain isolated effects on the prostate, which in the computer simulation remain modest compared to the reproducibility and reliability tested in our institution (Niemer et al. 1994). Also, the frequency of these errors was shown to be modest (15%) in our in vivo study. To minimize possible errors, we suggested, like others before us, to compare the number of step sections with the length of the prostate to be warned against missing steps, resulting in a smaller volume. In such cases the ultrasonographer might consider repeating the measurements. We certainly did not recommend the introduction of a fixed number of cross-sections (and, therefore, varying step sizes), nor the introduction of a critical area to define the first step.

Assessing the comments of Dr. Aarnink and his colleagues, we feel that we might not have made our point clear enough. Naturally, the salami effect does not change the thickness of slices measured perpendicular to the slice surface in planimetry, only their apparent thickness along the length axis of the ellipsoid. The salami and capsizing effect cause missing steps. Aarnink and colleagues correctly remark that missing steps due to angulation of the ellipsoids introduce errors. Angulation may even introduce extra steps when the height of the ellipsoid is almost as large as the length and the angulation is extreme (45°): we observed this in our model in very few cases, in which the measured volume exceeded the calculated volume by up to 0.6%. This extreme angulation is a rather uncommon phenomenon in urologic practice. However, we also observed a variation in volumetric error when no steps were missing according to ellipsoid length, so that this observation must have been introduced by the salami and capsizing effect. The combined relative error of the missing step together with this additional error is illustrated in the graphs of our article (Figs. 5 and 6).

When noting that the first step effect is independent of the height and width of the ellipsoid, Dr. Aarnink and his colleagues are correct, as long as the ellipsoid does not make rotational movements. In our example used to produce Table 1, we inadvertently did not state that this example-ellipsoid was capsized over 30°. Rotation makes the volumetry dependent on height and width. Subsequently, the shape of the ellipsoid influences the volumetric outcome.

Shape may clearly contribute to the volumetric error. Thus, simulation of a 50-mm ellipsoid with 5-mm step size is only identical to a 40-mm ellipsoid with 4-mm step size if length and height are decreased in the same proportion. In urologic practice, the shape of the prostate also influences, although less than volume, the image of the target organ that the clinician wishes to treat. Our article has been an attempt to improve on our understanding of the ultrasonic images we generate, leading to even greater accuracy and reproducibility.

REFERENCE


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