

TITLE: The effect of maternal body mass index on fetal ultrasound image quality

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Declaration of interest

J.A.N. and A.T.P. are cofounders of, and consult for, Intelligent Ultrasound Ltd. The other authors reports no conflict of interest.

Word count: 550

23 **Condensation:** Objective quality scores in >26,000 ultrasound images from routine fetal
24 mid-trimester examinations show a decline as maternal Body Mass Index increases,
25 resulting in clinically important and significant reductions in image quality.

26 **Key words:** anomaly scan, screening, quality assessment, body mass index, overweight,
27 ultrasonography, pregnancy, fetus, biometry

28 **Short title:** The effect of BMI on image quality

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31 Objective

32 More than 60% of women are overweight or obese in the United States, with obesity the
 33 most common clinical risk factor in obstetric practice¹⁻². Although increasing maternal Body
 34 Mass Index (BMI) is thought to be associated with lower ultrasound image quality²⁻⁴, no large
 35 scale studies have quantified the effect in real-world settings. We investigated the effect of
 36 BMI on image quality of standard fetal views at the time of the routine mid-trimester
 37 ultrasound.

38 Study Design

39 Retrospective analysis of ultrasound images, using a large real-world dataset, prospectively
 40 acquired at the John Radcliffe Hospital in Oxford, UK during routine anomaly screening (18-
 41 23 weeks of gestation) on 5 different ultrasound machines by 20 qualified sonographers.
 42 After IRB approval, all images were fully anonymized. Detailed, objective quality scoring⁵ of
 43 each ultrasound image (without knowledge of maternal BMI) was undertaken by a team of
 44 12 independent sonographers. We assessed six standard views: the transventricular and
 45 transcerebellar head views, abdominal circumference, femur length, sagittal spine, and
 46 coronal view of the lips. For each image, a quality score was generated⁵. Non-parametric
 47 testing was used to assess the association between BMI category (< 25, 25 to <30, 30 to
 48 <35; and ≥ 35) and quality on all images (pooled analysis, significance level set at <0.05)>
 49 We also assessed the impact of BMI on individual image criteria for each view.

50 Results

51 We assessed 26,954 ultrasound images from 3,251 women, with 1,788 (55%), 843 (26%),
 52 383 (12%) and 237 (7%) in the four BMI groups, respectively. There was a decrease in
 53 image quality with increasing maternal BMI for all views (**Error! Reference source not**
 54 **found.**, $p < 0.05$). Some clinical criteria were more affected by BMI than others (Figure): for
 55 instance the visibility of the cavum septi pellucidi in the transventricular and transcerebellar

56 views; and visibility of the umbilical vein in the abdominal circumference view decreased
57 most with higher BMI category. Magnification criteria were not significantly affected by BMI,
58 probably because magnification, a geometric criterion, does not directly relate to image
59 appearance and is under the control of the sonologist.

60 **Conclusions**

61 We assessed ultrasound images of standard fetal views taken during routine mid-trimester
62 ultrasound examinations; scored these images objectively; and assessed image quality by
63 maternal BMI. Using a large “real-world” image dataset acquired by a large number of
64 sonographers on multiple ultrasound machines we were able to show a consistent and
65 significant effect: the higher the maternal BMI category, the less likely fetal images were to
66 satisfy quality criteria, and some criteria were more affected than others (Figure). These
67 raise important clinical concerns: as an example, the poor visibility of the cavum septi
68 pellucidi with increasing BMI is important, as visualisation is an important marker of normal
69 brain development and closely associated with formation of the corpus callosum. In addition,
70 the finding that head, abdomen and femur views are affected by BMI category is of relevance
71 for fetal biometry, as measurements are performed on these images. Whether
72 measurements are less robust according to maternal BMI remains to be evaluated by
73 examining reproducibility of measurements in women with normal and high BMI. The largest
74 consecutive differences were between image scores for BMI categories 30 to <35 and at
75 least 35, suggesting that fetal image quality degrades most for maternal BMI ≥ 35 . This adds
76 an important limitation to imaging, information which should be shared with women attending
77 routine fetal anatomy scans.

78 **References**

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91 **Figure legend**

92 Figure: Comparison between BMI category (blue <25, orange = 25-29.9, grey = 30-34.9,
93 yellow ≥ 35), and the mean quality score for all images (main panel, $p < 0.05$). The mean
94 quality score for each criterion in each of the six standard views are shown in panels (a)
95 Head, trans-ventricular plane, (b) Sagittal view of the spine, (c) Abdominal circumference,
96 (d) Head in the transverse cerebellar plane, (e) Femur length and (f) coronal view of the lips.

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