Technoleg Iechyd Cymru
Health Technology Wales

Topic Exploration Report [1]

Cone-beam computed tomography for breast imaging

What is a Topic Exploration Report?

Topic Exploration Reports are not health technology assessments. These reports provide a high-level briefing on new topics submitted to Health Technology Wales and are not based on exhaustive or systematic literature searches. Instead, they rely on a focussed scan of key resources.

What evidence is used in a Topic Exploration Report?

Priority is given to summarising the most relevant or useful evidence, rather than covering all possible evidence. Information reported is typically based on abstracts and study authors' own conclusions, rather than detailed scrutiny of full texts.

What are the aims of a Topic Exploration Report?

Topic Exploration Reports offer an overview of the available evidence on a topic and aim to highlight any uncertainties or gaps in the evidence. These reports outline the quantity and type of evidence found, but no critical appraisal or formal evidence synthesis is conducted.

How should a Topic Exploration Report be used?

Topic Exploration Reports can be used to indicate what evidence may be available for a topic, and do not provide definitive guidance on how a technology should be used. The evidence presented within the reports should be interpreted with caution.

[1] Cyfieithu dogfennau HTW wedi'u cyhoeddi o'r Saesneg i'r Gymraeg
Translation of published technical HTW documents from English into Welsh

Topic exploration report number	TER594
Topic	Cone-beam computed tomography for breast imaging
Summary of findings	Breast screening is usually performed using full-field digital mammography. Magnetic resonance imaging (MRI) scans, computed tomography (CT) scans, and ultrasound may also be used to image breast tissue when investigating for cancer. Cone-beam breast computed tomography (CBBCT) is a novel imaging technique that can acquire 3D images of the breast in several seconds, does not require painful breast compression, and is claimed to provide more accurate results and detect smaller sized lesions. CBBCT could be used as an additional or replacement tool in the breast screening pathway. Three recent systematic reviews on the diagnostic accuracy of CBBCT were identified. CBBCT was reported to have good diagnostic performance in all reviews. The performance was lower than MRI in one review, but better than digital mammography in two reviews. There were no statistically significant differences compared to digital breast tomosynthesis. Six primary studies suggested CBBCT results could be used to discriminate various features of breast lesions and help predict or direct individualised treatment choices. Three primary studies investigated radiation dose during CBBCT and found it to be similar to that during mammography. Two primary studies found that comfort was generally improved with CBBCT compared with mammography. No economic studies were identified, and the impact of CBBCT on costs and resource use may vary depending on whether it is used as a replacement or complementary tool in the breast screening pathway. Small sample sizes were frequently mentioned as a limitation of the evidence and the age of some studies may mean device performance does not match currently available devices.

Introduction and aims

Breast cancer is the most common type of cancer in the UK, with over 50,000 new cases each year. Breast cancer screening is usually performed using full-field digital mammography, which involves taking two x-ray images (one from above and one from the side) of each breast whilst compressed. Magnetic resonance imaging (MRI) scans, computed tomography (CT) scans, ultrasound imaging, or a biopsy may also be used to investigate breast cancer. Breast cancer screening is available to women, and some trans and non-binary people, in Wales aged from 50 to 70 years. This involves being invited for a mammogram every three years. Some individuals at higher risk of breast cancer may be offered yearly mammograms, or MRI scans if under 40 years of age.

Cone-beam breast computed tomography (CBBCT) can be used to create high-resolution, three-dimensional images of breast tissue in as little as seven seconds, using less radiation than conventional CT. It is claimed to provide more accurate results for dense breast tissue and be able to detect smaller lesions than two-dimensional mammograms. It also does not involve compression of the breast, which can be painful for patients. This technology could potentially be used as complementary or replacement imaging modality in the breast screening pathway. This technology can be used to facilitate other procedures required for breast cancer; however, this report focuses on CBBCT's use for breast imaging and screening. Koning Vera CT is an example of a CBBCT device that has regulatory approval. This device can also take biopsies of breast tissue whilst the patient is in situ.

Health Technology Wales researchers searched for evidence on the clinical and cost effectiveness of CBBCT for breast imaging and screening.

Evidence overview

Diagnostic accuracy

Three recent systematic reviews, with meta-analyses, were identified examining the diagnostic accuracy of CBBCT.

Komolafe et al. (2022) meta-analysed studies on CBBCT and digital breast tomosynthesis (DBT), which uses multiple conventional x-ray mammograms to create 3D images. Five studies were included in the CBBCT arm and 17 studies in the DBT arm. The pooled sensitivities were 83.7% and 86.7%, respectively (p = 0.7622), whilst the pooled specificities were 71.3% and 87.0%, respectively. Pooled positive likelihood ratios were 2.71 and 6.28 in the CBBCT and DBT arms, respectively, and pooled negative likelihood ratios were 0.17 and 0.20. The 95% confidence intervals (CI) for all of these outcomes overlapped for the two interventions. The areas under the ROC (AUC) were 0.925 for DBT and 0.831 for CBBCT. The authors concluded that DBT showed improved diagnostic performance over CBBCT, however there was no statistically significant difference in any diagnostic measures.

Gong et al. (2023) carried out a systematic review comparing CBBCT to various other breast imaging modalities. They included 18 studies, with a total n = 1,792, and found the pooled sensitivity and specificity (95% CI) of CBBCT in diagnosing breast cancer to be 0.95 (0.91 to 0.97) and 0.72 (0.62 to 0.80), respectively. The AUC of CBBCT was 0.92 (0.90 to 0.94), showing high overall accuracy. The authors also reported head-to-head comparisons of imaging modalities and found that CBBCT was superior to digital mammography (AUC 0.94 [0.92 to 0.96] vs. 0.83 [0.80 to 0.83], 8 studies, total n = 992) and inferior to MRI (AUC 0.88 [0.85 to 0.91] vs. 0.96 [0.94 to 0.97], 4 studies, total n = 203).

Yang et al. (2024) carried out a systematic review and meta-analysis to compare the diagnostic performance of CBBCT and mammography in identifying primary breast cancer. Eight studies

were included, and the pooled sensitivity (95% CI) was significantly higher for CBBCT at 0.92 (0.87 to 0.94) compared with 0.77 (0.69 to 0.83) for mammography, $p < 0.001$. The pooled specificities were similar between the two modalities (0.79 [0.71 to 0.85] for CBBCT and 0.75 [0.66 to 0.82] for mammography). The overall accuracy, as represented by AUC, was also significantly higher for CBBCT than mammography (0.93 [0.90 to 0.95] and 0.83 [0.80 to 0.86], respectively, $p < 0.001$).

Determining features of breast cancer/potential care

Several primary studies have suggested that the images obtained using CBBCT could be used to aid in discriminating the type of cancer and making decisions on care.

Li et al. (2021) found that tumour-to-gland volume ratio and tumour-to-breast volume ratio measured using CBBCT are correlated with type of surgery chosen (breast-conserving or mastectomy) in a retrospective study of 200 participants. They suggested these ratios could be used to help surgeons determine whether breast-conserving surgery is an option. Ma et al. (2022a) found that tumour-to-breast volume ratio, as well as rim enhancement pattern and presence of penetrating vessels, from contrast-enhanced CBBCT images were significant predictors of prognostic stage II/III disease.

Studies by Uhlig et al. (2017), Ma et al. (2021) and Zhu et al. (2020) found that contrast enhancement during CBBCT can help distinguish molecular subtypes of breast cancer and then help direct individual treatment decisions. Kang et al. (2021) found that CBBCT results had a high specificity and positive predictive value in predicting whether non-mass enhancement lesions were malignant in a study of 84 lesions.

Ma et al. (2022b) compared the ability of contrast-enhanced CBBCT and MRI to determine background parenchymal enhancement (BPE) levels. In a retrospective study of 221 participants, there was substantial agreement between the two imaging modalities for BPE evaluation and the inter-reader reliability was comparable between them.

Radiation dose

Three studies were identified that examined the radiation dose received during CBBCT. A prospective study of 23 women found the average glandular radiation dose during mammography was 6.5 ± 2.9 mGy and 8.2 ± 1.4 mGy during CBBCT (O'Connell et al. 2010). However, the range of doses received during CBBCT were all within the range received during mammography. Another study of 36 participants found that radiation dose was similar or less with CBBCT than mammography, with mean doses of 9.4 ± 3.1 mGy and 16.9 ± 6.9 mGy, respectively (O'Connell and Kawakyu-O'Connor 2012). A third study of 132 women found the mean glandular dose for CBBCT was higher at 13.9 ± 4.6 mGy compared with 12.4 ± 6.3 mGy for mammography, whilst the range and interquartile range were lower for CBBCT (Vedantham et al. 2013). The likelihood of either modality leading to lower radiation dose was approximately equal.

Comfort

A prospective study of 409 participants comparing the comfort of CBBCT and mammography found that CBBCT was generally more comfortable for patients than mammography (Li et al. 2019). Comfort scores were statistically significantly better for CBBCT overall and in the subgroups of non-contrast enhanced, contrast enhanced, those aged 44 years or under, those aged 45 to 59 years, those with BMI over 18.5, the fatty-breast group, and the dense-breast group ($p < 0.05$). There was no statistically significant difference in comfort between imaging modalities in those aged 60 years and over or those with BMI under 18.5. Greater comfort during CBBCT, compared to mammography, was also reported in a pilot study (O'Connell and Kawakyu-O'Connor 2012).

Areas of uncertainty
• Several studies and systematic reviews mention small sample sizes as limitations. • The age of some included studies may mean the devices used may not match the performance standards of currently available devices. • No economic studies were identified. • The impact of CBBCT on service outcomes, costs, and resource use may vary depending on whether it is used as a replacement or a complementary technique in the breast screening pathway.

Literature search results

Evidence reviews and economic evaluations

Gong W, Zhu J, Hong C, et al. (2023). Diagnostic accuracy of cone-beam breast computed tomography and head-to-head comparison of digital mammography, magnetic resonance imaging and cone-beam breast computed tomography for breast cancer: a systematic review and meta-analysis. Gland Surg. 12(10): 1360-74. doi: https://doi.org/10.21037/gs-23-153

Komolafe TE, Zhang C, Olagbaju OA, et al. (2022). Comparison of Diagnostic Test Accuracy of Cone-Beam Breast Computed Tomography and Digital Breast Tomosynthesis for Breast Cancer: A Systematic Review and Meta-Analysis Approach. Sensors (Basel). 22(9). doi: https://doi.org/10.3390/s22093594

Yang L, Zhou Z, Wang J, et al. (2024). Head-to-head comparison of cone-beam breast computed tomography and mammography in the diagnosis of primary breast cancer: A systematic review and meta-analysis. Eur J Radiol. 171: 111292. doi: https://doi.org/10.1016/j.ejrad.2024.111292

Individual studies

Ma Y, Liu A, O'Connell AM, et al. (2021). Contrast-enhanced cone beam breast CT features of breast cancers: correlation with immunohistochemical receptors and molecular subtypes. Eur Radiol. 31(4): 2580-9. doi: https://doi.org/10.1007/s00330-020-07277-8

Ma Y, Liu A, Zhang Y, et al. (2022b). Comparison of background parenchymal enhancement (BPE) on contrast-enhanced cone-beam breast CT (CE-CBBCT) and breast MRI. Eur Radiol. 32(8): 5773-82. doi: https://doi.org/10.1007/s00330-022-08699-2

Uhlig J, Fischer U, von Fintel E, et al. (2017). Contrast Enhancement on Cone-Beam Breast-CT for Discrimination of Breast Cancer Immunohistochemical Subtypes. Transl Oncol. 10(6): 904-10. doi: https://doi.org/10.1016/j.tranon.2017.08.010

Zhu Y, Zhang Y, Ma Y, et al. (2020). Cone-beam breast CT features associated with HER2/neu overexpression in patients with primary breast cancer. Eur Radiol. 30(5): 2731-9. doi: https://doi.org/10.1007/s00330-019-06587-w

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Kang W, Zhong W, Su D. (2021). The cone-beam breast computed tomography characteristics of breast non-mass enhancement lesions. Acta Radiol. 62(10): 1298-308. doi: https://doi.org/10.1177/0284185120963923

Li H, Yin L, He N, et al. (2019). Comparison of comfort between cone beam breast computed tomography and digital mammography. European Journal of Radiology. 120: 108674. doi: https://doi.org/10.1016/j.ejrad.2019.108674

Li J, Zhong G, Wang K, et al. (2021). Tumor-to-Gland Volume Ratio versus Tumor-to-Breast Ratio as Measured on CBBCT: Possible Predictors of Breast-Conserving Surgery. Cancer Manag Res. 13: 4463-71. doi: https://doi.org/10.2147/cmar.S312288

Ma WM, Li J, Chen SG, et al. (2022a). Correlation between contrast-enhanced cone-beam breast computed tomography features and prognostic staging in breast cancer. Br J Radiol. 95(1132): 20210466. doi: https://doi.org/10.1259/bjr.20210466

O'Connell A, Conover DL, Zhang Y, et al. (2010). Cone-beam CT for breast imaging: Radiation dose, breast coverage, and image quality. AJR Am J Roentgenol. 195(2): 496-509. doi: https://doi.org/10.2214/ajr.08.1017

O'Connell AM, Kawakyu-O'Connor D. (2012). Dedicated Cone-beam Breast Computed Tomography and Diagnostic Mammography: Comparison of Radiation Dose, Patient Comfort, And Qualitative Review of

Imaging Findings in BI-RADS 4 and 5 Lesions. J Clin Imaging Sci. 2: 7. doi: https://doi.org/10.4103/2156-7514.93274

Vedantham S, Shi L, Karellas A, et al. (2013). Personalized estimates of radiation dose from dedicated breast CT in a diagnostic population and comparison with diagnostic mammography. Phys Med Biol. 58(22): 7921-36. doi: https://doi.org/10.1088/0031-9155/58/22/7921

Date of search	25 February 2025
Concepts used	Koning Vera CT, computed tomography, CT, cone-beam, breast, cancer

Proposed research question and evidence selection criteria (if selected)

Proposed Research question	**What is the clinical and cost effectiveness of cone-beam computed tomography for breast imaging?**

	Inclusion criteria	Exclusion criteria
Population	People undergoing breast screening	
Intervention	Cone-beam breast computed tomography	
Comparison/ Comparators	X-ray mammography Digital breast tomosynthesis MRI CT Ultrasound	
Outcome measures	Diagnostic accuracy including sensitivity, specificity, positive predictive value, negative predictive value (reference standard: biopsy) Time to diagnosis Time to treatment Patient acceptability and comfort Radiation dose Health related QoL Resource use Economic outcomes	

Proposed speciality	Cancer