Reduction in Breast Radiation Dose during Abdominal CT using Breast Displacement

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**Purpose**

There is increasing recognition that female breast tissue is one of the most radiosensitive tissues in the human body, as reflected by the 140% increase in the tissue weighting factor by the 2008 International Commission on Radiological Protection (ICRP) update. (1) It is therefore not surprising that radiation dose to female breast tissue has been the target of dose reduction efforts in recent years.

There are multiple well-accepted techniques and evolving strategies for reducing breast radiation dose during computed tomography (CT). These include direct in-plane shielding with bismuth or lead and various types of automatic exposure control. (2-4) Recently, cranial breast displacement has been shown to reduce breast surface radiation dose by a mean of 24% during coronary CT angiography (CTA). (5) In that study, the greatest benefit was seen in larger breasts and in the upper quadrants and areolar region of the breast.

By virtue of the position of the breasts on the lower chest, breast tissue lies within the scanning field on abdominal CT that includes the diaphragmatic cupolae. An anthropomorphic phantom study showed breast radiation doses of 0.2-2.4 cGy for abdominopelvic CT for appendicitis (mean effective exam dose 13.3 mSv), compared with breast radiation dose of 4.3-6.6 cGy for chest CT for pulmonary embolism (mean effective exam dose 14.4 mSv). (6) These idealized measures likely underestimate the real radiation dose received in clinical practice, particularly in larger women. (7)

The aim of this study was to investigate if cranial breast displacement decreases breast skin entrance radiation dose during abdominal multidetector CT (MDCT) in clinical practice at a tertiary teaching hospital in the in- and outpatient setting.
Fig. 4: Chrysalis device on volunteer

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Methods and Materials

This prospective, randomized single-center clinical efficiency trial received Institutional Review Board approval.

Following written consent in English, women 18-60 years of age undergoing single- or multi-phase abdominal CT were randomized to wear a cranial breast displacement device, Chrysalis CT device (Meta Imaging Solutions, LLC, Columbia MO), or to not. Controls were matched for breast size and underwent CT without breast displacement. Patients undergoing CT KUB were excluded, since this exam does not typically include the diaphragm and therefore may not include the inframammary fold. Patients undergoing CT of both the chest and abdomen were also excluded, since breast displacement during chest CT may actually increase breast dose in the setting of tube current modulation due to displacement of the breasts into the shoulder girdle.

Four thermoluminescent dosimeters (TLDs) were affixed to each breast of all subjects by the female investigator (C.S.) or, if she was unavailable, a female technologist. Overall CT radiation dose was highly variable between subjects, because of the inclusion of both single and multi-phase exams, acquisition of images on one of several CT scanners, and use of tube current modulation on all exams. Rather than measuring absolute dose reduction, relative radiation dose was assessed by TLD placement as depicted in Fig. 1. The lowest TLD on each breast was placed on the upper abdominal wall just below the inframammary fold (location 1 on Fig. 1) and was within the scan plane, thus serving as an internal control. The other TLDs were placed on the lower outer quadrant (location 2), on the medial areola (location 3), and on the upper outer quadrant (location 4) of each breast. Relative radiation dose could then be calculated at the three breast sites relative to the ipsilateral inframammary TLD.

For those subjects undergoing placement of the Chrysalis device, breast displacement was performed by the female investigator (C.S.) or, if she was unavailable, a female technologist. The Chrysalis device was pre-assembled to fit the subject based on self-reported chest size, by combining the main panel (Fig. 2) with necessary extension panels (Fig. 3).

Automatic tube current modulation and bismuth breast shield were used with all subjects. The study was powered for a relative dose reduction with breast displacement of greater than 10% to represent a clinically important benefit.

Univariate analysis of patient characteristics in the study and control groups were performed, using Student t-test and or chi-square test as appropriate. Subsequently,
unadjusted and adjusted linear regression models were fitted for study versus control group. Evaluated covariates included patient age, body mass index and breast size. Breast size was also evaluated for effect modification.
Fig. 1: TLD location on chest

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Fig. 2: Chrysalis device, main panel

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**Fig. 3:** Chrysalis device, Extension panels

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Fig. 4: Chrysalis device on volunteer

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Results

We enrolled 50 women (mean age: 41 years (+/- 13.3); age range, 18-60 years) with a mean body mass index (BMI) of 41, range 19-47.5. Sixteen subjects had small breasts (cup size A or B), 17 had medium breasts (cup size C), and 17 had large breasts (D or higher).

Of the approached patients who met inclusion criteria, 19 declined to participate in the study.

All enrolled study subjects completed the CT scan. Breast displacement device application did not interfere with clinical work flow and no adverse effects due to device placement were observed.

When breasts are displaced cranially during abdominal CT, mean dose reduction in relative breast skin dose to the lower outer quadrant of the breast and areola is about 14% (CI 4-24%), compared with nondisplaced breast tissue (unadjusted and adjusted linear regression) (Fig. 5). No significant change in relative breast dose was achieved at the upper outer quadrant of the breast.

Stratification for cup size, BMI, and age did not show significant change in results.
Fig. 5: Mean skin entrance dose at lower outer quadrant and areola relative to inframammary TLD location in Control and Chrysalis subjects

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Conclusion

Clinical relevance:

Some dose reduction to the breast is achieved when using Chrysalis CT device for cranial breast displacement during abdominal CT in this clinical efficiency trial. The device is well tolerated but, at least in our institution, requires a female radiologist or technologist to place the device.

Outlook:

Though there is recent evidence that breast displacement by the Chrysalis CT device during coronary CTA reduces radiation dose and may improve image quality, we found that its use during abdominal CT did not decrease radiation dose by a magnitude compelling enough to implement in daily use for abdominal imaging.
References


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