Dual-energy CT for the evaluation of silicone breast implants

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Abstract

Objective The evaluation of breast implants for rupture is currently the domain of ultrasound and MRI, while mammography is of very limited diagnostic value. Recently, specific visualisation of silicone has become feasible using dual-energy CT. Our objective was to evaluate whether it is feasible to identify silicone in breast implants by dual-energy CT and to reliably diagnose or rule out ruptures.

Methods Seven silicone breast implant specimens were examined on dual-source CT at 100- and 140-kV tube potential with a 0.8-mm tin filter (collimation 128 × 0.6 mm, current–time products 165 and 140 mAsref with modulation, rotation time 0.28 s, pitch 0.55). Two patients scheduled for implant removal or replacement were examined with identical parameters.

Results The silicone of the implant specimens showed a strong dual-energy signal. In one patient, both implants were intact, while a rupture was identified in the other patient. Ultrasound, MRI, surgical findings and histology confirmed the dual-energy CT diagnosis.

Conclusion Dual-energy CT may serve as an alternative technique for speedy evaluation of silicone breast implants. Specific clinical studies are required to determine the diagnostic accuracy and define indications for this technique.

Key Points

- *Dual-energy CT makes it possible to visualise silicone in breast implants.*
- *Silicone provides a strong photoelectric effect that can be detected.*
- *Initial experience suggests that implant ruptures can be identified or ruled out.*

Keywords Dual-energy CT · Breast implants · Augmentation · Silicone · Implant rupture

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Introduction

Breast augmentation is common throughout the world, be it for cosmetic or reconstructive purposes. Silicone and saline implants are the most common type of augmentation, and both represent a challenge for imaging. Recently, the problems concerning the French manufacturer PIP (Poly Implant Prothèse, La Seyne-sur-Mer, France), which used low-grade industrial silicone for most of their implants, sparked an increase in demand for medical imaging to evaluate breast implants in many countries [1]. French health authorities recommended close follow-up at 6-month intervals for all patients with intact PIP implants and immediate removal of ruptured implants [2].

The most frequent and relevant diagnostic question in this context is implant integrity. After implantation, the body physiologically builds a layer of fibrous tissue around the implant as a physiological reaction to the foreign material, forming a fibrous capsule [3]. Implant rupture can be classified as intracapsular or extracapsular, depending on the location of the escaped silicone with respect to this fibrous capsule. Most implant ruptures remain intracapsular. The median life expectancy of normal quality silicone implants is around 10–16 years and is related to the thickness and quality of the elastomer shell [4]. Another aspect of leakage is 'gel bleed', which represents a transudation of microscopic amounts of silicone gel through an intact shell. Recent studies revealed that PIP prostheses rupture and bleed more frequently [5–7] and that low-quality silicone gel can cause irritation and local inflammation, although there is no evidence of carcinogenic effects [8].

For cancer screening, mammography can be performed as implant-displaced projections (Eklund technique) in order to optimally visualise the glandular tissue anterior to the implant. However, silicone implants appear as dense oval masses that are too radiodense to allow a diagnostic evaluation using the x-ray spectrum of mammography [9]. The rupture only becomes apparent if there is an extracapsular rupture and large conglomerates of radio-opaque silicone are seen in the glandular parenchyma or in axillary lymph nodes.

Therefore, the evaluation of implants is currently in the domain of ultrasound and MRI [9]. In ultrasound, the shell is visualised as single or double echogenic lines, and their continuity can be evaluated to exclude rupture. A reliable sign of intracapsular rupture is multiple curvilinear lines crossing through the interior of the implant, called the "stepladder" sign [10]. Also, in the case of extracapsular rupture, silicone conglomerates in the glandular parenchyma or in axillary lymph nodes can be recognised by increased echogenicity ("snowstorm sign") and strong posterior shadowing. The reported sensitivity and specificity of ultrasound for implant rupture are around 50–77 % and 55–84 %, respectively [11, 12].

The best diagnostic option for implant evaluation is MRI with a reported sensitivity of 74–100 % and specificity of 63–100 %, depending on the technique, with significant progress in MRI over the last years [4, 13–19] . Intracapsular rupture is recognised as the "linguine sign" based on hypointense lines of the shell in the bright signal of the silicone in T2-weighted sequences or the "salad oil" sign with round "drops" of altered signal from small inclusions of fluid within the silicone. Since recently, there are silicone-specific sequences using three-point chemical-shift techniques [20] to highlight silicone in the glandular parenchyma or in axillary lymph nodes with

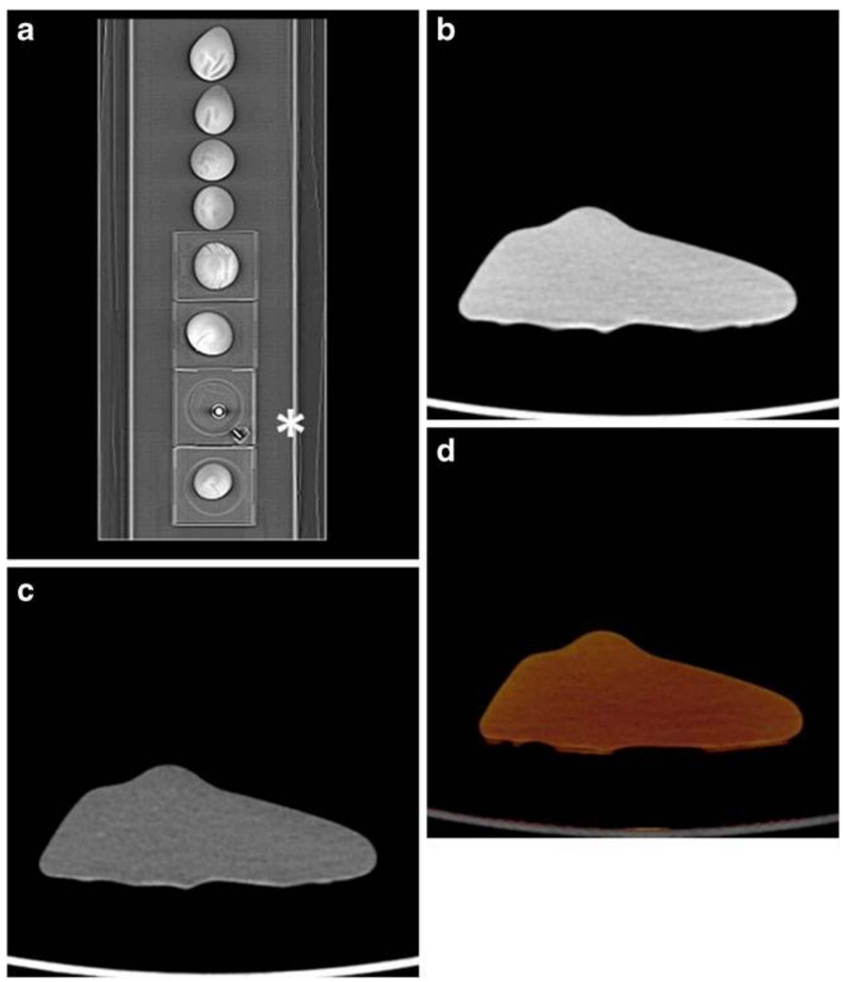

Fig. 1 Topogram showing seven different silicone breast implant specimens and one spacer [*] (**a**). CT images of a silicone implant obtained simultaneously at 100 (**b**) and Sn 140 kVp (**c**). *Colour coding* of the photoelectric effect shows homogeneous signal in the implant (**d**)

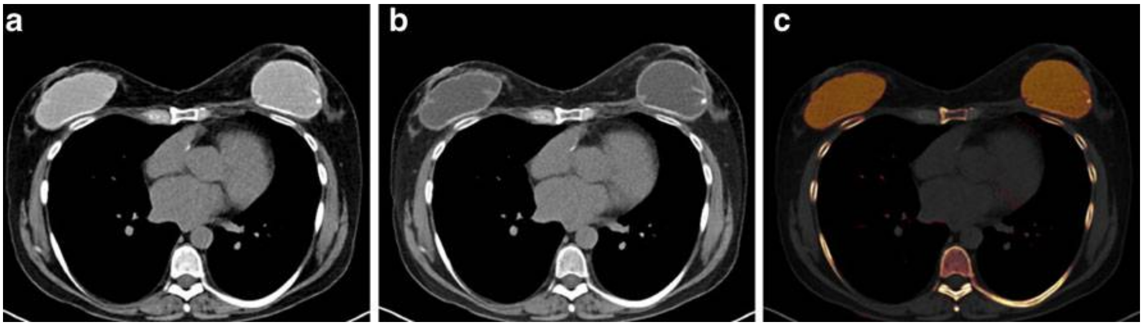

Fig. 2 A 48-year-old patient (patient A) examined for implant evaluation; CT images obtained simultaneously at 100 (**a**) and Sn 140 kVp (**b**) and colour-coded silicone (**c**). There is strong signal from the silicone and no evidence of rupture

high signal, which are helpful for the detection of small extracapsular ruptures. On the other hand, there are specific diffusion-weighted sequences for cancer detection in implant patients suppressing the signal of both fat and silicone [21].

Although MRI represents the technique of choice, in some patients with contraindications, e.g. pacemakers, cochlear implants, or other metallic implants or foreign bodies, or in the case of severe claustrophobia, other diagnostic options would be desirable.

So far, CT has not played a role in the evaluation of the breast or implants. However, dual-energy CT has been clinically available since 2006, offering the possibility of acquiring two CT data sets at the same time using different x-ray spectra. The two data sets can be analysed voxel by voxel using a three-material decomposition algorithm in order to identify materials with photoelectric effect. Chemically, silicone or polymerised siloxanes consist of light atoms such as hydrogen, carbon, and oxygen, but also the metalloid element silicon with element number 14. Contrary to the lighter atoms, this element has a significant photoelectric effect, which can be visualised in dual-energy CT [22]. Therefore, the aim of this initial investigation was to evaluate whether it is feasible to identify silicone in breast implants by dual-energy CT and whether the image quality and contrast-to-noise ratio are sufficient to reliably identify or rule out ruptures. A secondary aim was to evaluate whether different types of silicone implants could be differentiated, because the imaging characteristics of PIP implants do not differ from those of other types of prostheses in other techniques [23] and many patients do not know which type of implant they have.

Materials and methods

Seven different silicone breast implants were examined using dual-source CT (Somatom Definition Flash, Siemens, Forchheim, Germany). Manufacturers of the prostheses were Mentor (Santa Barbara, CA, USA; three implants), Natrelle by Allergan (Marlow, Buckinghamshire, UK; two implants), Eurosilicone (Apt, France), and Poly Implat Prothèse (PIP, La Seyne-sur-Mer, France). The examination was performed using standard parameters for dual-energy CT of the chest, which are routinely used for lung perfusion imaging: voltages 140 kVp with 0.8–mm tin filter and 100 kVp; collimation 128 × 0.6 mm, reference tube current–time products (CareDose4D) 165 and 140 mAs, rotation time 0.28 s and pitch 0.55. The implants were centred on the patient table in the gantry. The resulting images were analysed using the three-material decomposition algorithm

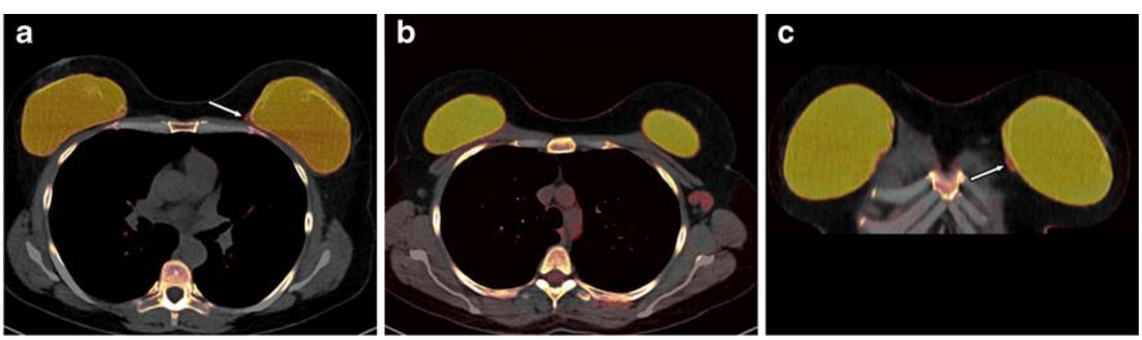

Fig. 3 A 51-year-old female patient (patient B) examined for the evaluation of PIP implants before surgical removal; CT images in axial (**a**, **b**) and coronal (**c**) orientation with colour-coded silicone signal. Note the silicone extending outside the inferior medial shell of the left implant (*arrows* in **a** and **c**) and the silicone signal in the enlarged axillary lymph node (**b**)

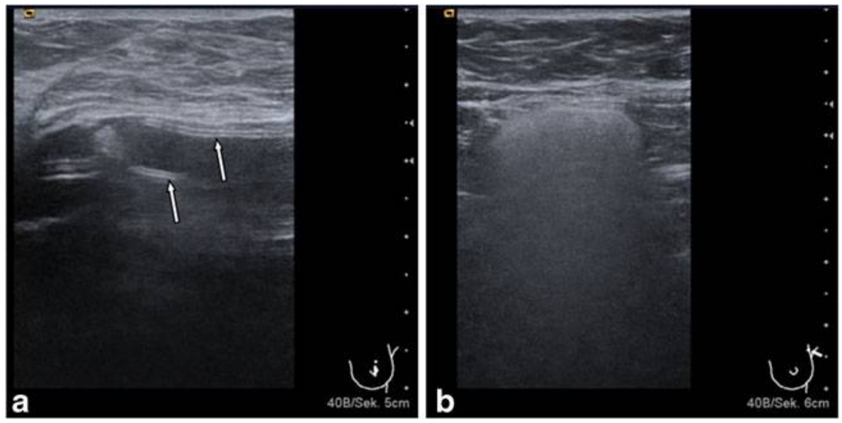

Fig. 4 Ultrasound images of patient B showing a "stepladder" sign of the implant (*arrows* in **a**) and increased echogenicity of the corresponding enlarged axillary lymph node (**b**)

[22] of the dual-energy CT software (syngo VE32B) with the "Liver VNC" preset.

After the technical feasibility had been confirmed, two patients were examined. Both presented for breast implant evaluation before implant replacement or removal and were reluctant to undergo MRI owing to claustrophobia. Written informed consent was obtained before the examination after the nature of the procedure had been fully explained. One of the patients (patient A, 48 years old) had Mentor implants on both sides, which appeared intact on ultrasound. The other 51-year-old patient (patient B) had PIP implants, one of which had already been replaced with a new PIP implant. Ultrasound had shown signs of implant rupture in this patient.

The same parameters as mentioned above were used for the patient examinations. The patient table was positioned rather low in the gantry in order to ensure that the implants were entirely covered by the 33–cm field of view of the smaller detector. The examination range was limited to include the implants and axillary lymph nodes. No contrast material was applied. Examination times were 3 and 4 s. The CT dose index was 7.7 mGy and 8.1 mGy, the DLP 132 and 158 mGy*cm, converting to equivalent doses of 2.2 and 2.7 mSv [24].

Results

The implants showed a strong dual-energy signal of both the silicone inside the implant and the elastomer shell with a contrast-to-noise ratio of 8 ± 1 (Fig. 1). There were small differences in the individual density values of the specimen implants (ranges 115–131 HU at 100 kVp vs. 7–21 HU at Sn140kVp). There were also slight differences in density in different areas of the same implant, depending on the configuration and resulting differences in beam hardening and cupping artefacts. Thus, the differences in density between the prostheses of different suppliers were not significant and would not allow a differentiation.

In the patient examinations, the density values in both patients were equivalent (104 HU at 100 kVp/6 HU at Sn140kVp). Colour coding of the silicone highlighted the implants with strong contrast and very weak noise in surrounding tissue. In patient A, the silicone signal was confined to the envelope of the implants (Fig. 2). In patient B with the PIP prostheses, an extracapsular rupture was identified in the posterior lower inner aspect of the left implant (Fig. 3). The shell also showed multiple folds and layers crossing the silicone inside, suggesting a rupture and collapse of the shell.

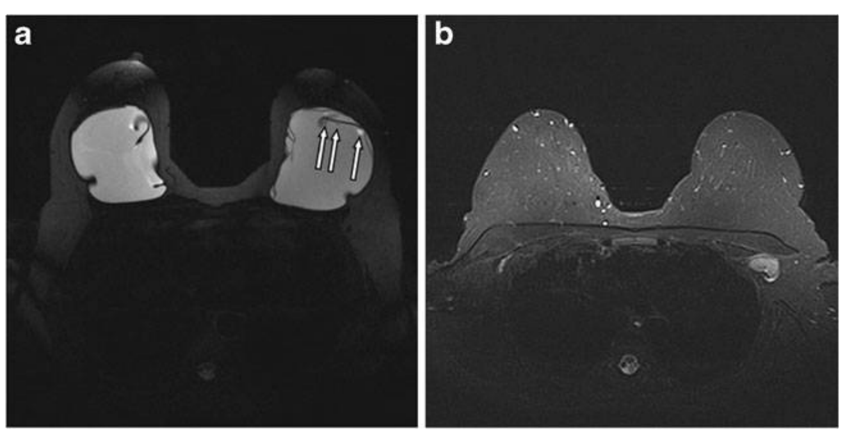

Fig. 5 MRI of patient B showing a "salad oil" sign in the left implant on T2-weighted sequences (*arrows* in **a**) and increased signal of the enlarged left axillary lymph node on silicone-specific sequences (**b**)

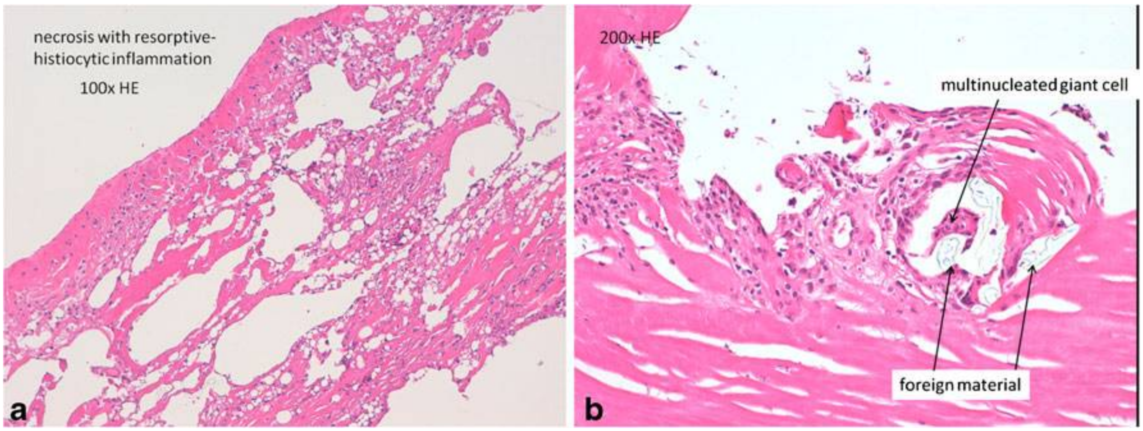

Fig. 6 Histology of patient B showing necrosis with resorptive histiocytic inflammation (**a**) and formation of granulomas with multinucleated giant cells around foreign material (**b**)

There were enlarged axillary lymph nodes on the same side, which also showed a strong silicone signal.

Ultrasound images had been acquired at initial presentation and were available for correlation in both patients. There was no sign of rupture in patient A, whose implants appeared intact on CT. In patient B with the suspected rupture, ultrasound showed a "stepladder" sign of the implant and a "snowstorm" sign in the axillary lymph node on the same side (Fig. 4). With the ultrasound and CT findings suggesting implant rupture, patient B then agreed to MRI with sedation for surgical planning. MRI also indicated rupture of the left implant with "linguine" and "salad oil" signs in the implant and strong signal in the axillary lymph node in silicone-specific sequences (Fig. 5).

Surgery confirmed the findings in both patients. The Mentor prostheses of patient A were explanted without complication. In patient B with PIP implants, the left implant was very fragile and completely disintegrated at explantation. The right implant was found intact and explanted without complications. Adhering to current pertinent guidelines [25], the axillary lymph nodes were not sampled or resected.

In patient B, histology confirmed silicone outside the implant with the formation of granulomas in the tissue medial and inferior of the implant (Fig. 6).

Discussion

The diagnostic evaluation of the breast after augmentation remains a challenge in several respects. MRI is obviously the technique of choice but is time consuming and expensive and may yield a substantial number of false-positive results in a cancer screening setting. Also, there is a small number of patients in whom contraindications or claustrophobia curtail its use. In the literature, it is also being discussed controversially whether general health insurance should pay for more expensive screening techniques or even for the follow-up of the implant after an augmentation for cosmetic purposes [1, 26–28].

Based on our initial results, it seems that dual-energy CT might become an option for implant evaluation in particular cases, especially if there are contraindications for MRI. Of course, in contrast to emerging high-resolution breast CT [29], the technique is not sufficient to simultaneously screen for cancer and implies exposure to ionising radiation. The equivalent dose of 2.2 and 2.7 mSv in our patients was well below the reference limit for chest examinations (DLP 400 mGy*cm[30]). In conventional mammography, patients with implants receive higher radiation doses owing to the density of the implants, amounting to some 10.7 mGy per breast or a total equivalent dose of 2.6 mSv [31, 32], so the overall dose is comparable. Thus, weighing the health risks of a ruptured implant against the low risk of radiation-induced cancer, the indication may appear similar as in many other diseases that are routinely evaluated by CT. A strength of the technique is the specific depiction of silicone without the administration of contrast material, so there are no other side effects or risks. The diagnostic value of the two initial patient examinations, clearly showing a strong silicone signal and indicating implant rupture and silicone in the axillary lymph nodes in one of the patients, seems to justify the use of this technique.

In conclusion, dual-energy CT offers the possibility of specifically visualising silicone, making it feasible to evaluate breast implants for rupture. Thus, dual-energy CT may serve as an alternative technique, especially for patients with contraindications for MRI. A systematic clinical trial will be required to determine the diagnostic accuracy of this technique and to define appropriate indications.

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