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Evaluation of techniques for detecting breast implant rupture

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MISSION

The mission of the *Agence d'évaluation des technologies et des modes d'intervention en santé* (AETMIS) is to contribute to improving the Québec health-care system and to participate in the implementation of the Québec government's scientific policy. In order to accomplish this, the Agency advises and supports the Minister of Research, Science and Technology as well as the decision-makers in the health-care system with respect to the assessment of health services and technologies. The Agency makes recommendations based on scientific reports assessing the introduction, distribution and application of health technologies, including technical aids for disabled persons, as well as the modes of providing and organizing services. The assessments take into account multiple factors, such as efficacy, safety and efficiency, as well as ethical, social, organizational and economic implications.

FOREWORD

EVALUATION OF TECHNIQUES FOR DETECTING BREAST IMPLANT RUPTURE

Over the past few years, the safety of silicone gel-filled breast implants has raised a great deal of concern among women, for study reports have suggested a link between such implants and the occurrence of local and systemic complications. Because of this potential health risk, the sale of these implants was halted, even if the toxicity of silicone has not been demonstrated by scientific data. The most frequent local complication is implant shell rupture, which results in exposure of the body to silicone and in a loss of esthetics.

Several imaging techniques are capable of detecting breast implant rupture, but their efficacy, cost and accessibility vary considerably. This being the case, the Québec Minister of Health and Social Services asked the Agence d'évaluation des technologies et des modes d'intervention en santé (AETMIS) to evaluate the efficacy of mammography in detecting breast implant rupture and to assess the potential risks associated with this technique in order to determine if they warrant the use of an alternative method, such as magnetic resonance imaging (MRI).

AETMIS closely examined several recent reports on the detection of breast implant rupture and analyzed published studies postdating these reports. Like other assessment organizations, AETMIS notes that, based on the current state of knowledge, instituting a breast implant rupture screening program cannot be justified. Furthermore, the scientific data do not show that the breast compression required during mammography causes implant rupture, although it can, at the very most, exacerbate an acquired or existing defect.

To issue recommendations concerning the detection of breast implant rupture, one must, on the one hand, examine the efficacy, accessibility and cost of the imaging techniques that are normally used, i.e., mammography, ultrasonography and MRI, and, on the other hand, establish that silicone has no toxic effects. In light of these criteria, AETMIS recommends a mammographic examination followed by a breast ultrasound as the first-line strategy in all cases where implant rupture is suspected on clinical examination. MRI should be reserved for those cases where the results of these two techniques are equivocal or suspicious or when the results of the clinical and radiological examinations are discordant.

In disseminating this report, AETMIS wishes to provide the best possible information to the policymakers concerned by this issue in Québec's health-care system.

Renaldo N. Battista
President and Chief Executive Officer

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SUMMARY

INTRODUCTION

Breast implants are used for breast reconstruction after mastectomy or an accident, for correcting congenital malformations, such as breast aplasia, hypoplasia or asymmetry, and for breast augmentation for cosmetic purposes. Up until 1991, most breast implants consisted of a strong silicone shell containing silicone gel. Although the scientific data do not show silicone to be toxic, the potential health risks associated with silicone breast implants led to the voluntary withdrawal of these products from the market and to a moratorium being imposed on their use in Canada and the United States. This moratorium, which was adopted in January 1992, is still in effect.

Silicone implants have been associated with local and systemic complications. The most frequent local complication is implant shell rupture, which results in exposure of the body to silicone and in a loss of esthetics. Breast implant rupture can be detected by mammography, ultrasonography and magnetic resonance imaging (MRI). The purpose of this report, which stems from a request by the Minister of Health and Social Services, is to examine the efficacy of mammography in detecting implant rupture and the potential risks associated with this technique, in order to determine if these risks justify the use of an alternative imaging modality, such as MRI.

METHODOLOGY

This report examines published scientific data and bases itself mainly on the conclusions of reports published by the following three organizations: the Agence Nationale d'Accréditation et d'Évaluation en Santé, formerly the Agence Nationale pour le Développement de l'Évaluation Médicale (ANDEM), the Independent Review Group (IRG) in the United Kingdom and the Institute of Medicine (IOM) in the United States. The recentness of these reports, the extent and quality of the resources used to prepare them, the exhaustiveness of the studies examined and the rigour of the analyses performed guarantee the validity of these organizations' conclusions. This detailed examination of the reports was supplemented by an analysis of studies published between January 1999 and August 2001. Lastly, we documented the current practice in Québec by consulting health professionals.

BREAST IMPLANT INTEGRITY

Implant rupture consists of a tear in the shell, which results in the extravasation of the silicone gel into the fibrous capsule (intracapsular rupture) or into the surrounding tissues (extracapsular rupture). Intracapsular rupture, which is the more frequent type, is usually asymptomatic, is undetectable on clinical examination and mammography, and does not cause any breast deformity. There is no consensus as to the indication for implant removal in such cases. Extracapsular rupture, which is a much rarer occurrence, results in the silicone spreading into the breast tissues or distantly into the thoracic cavity, upper limbs or pelvic region, causing breast deformity and a loss of esthetics. This type of rupture constitutes an indication for removal.

The prevalence of rupture depends on the type and model of implant, the implant's physical characteristics, the quality of the shell, and other factors, such as trauma, the compression used during capsulotomy, and wear and aging of the implant. Breast compression during mammography has been suggested as a possible cause of rupture, but the link between mammography and breast implant rupture is not supported by scientific data. However, mammography could exacerbate a preexisting defect or cause an intracapsular rupture to become extracapsular.

BREAST IMPLANTS AND BREAST IMAGING

Evaluating implant integrity

The diagnostic techniques assessed in this report are mammography, ultrasonography and MRI. A literature search only revealed case series in which the reference test was surgery and which met preestablished criteria. The series were small and included women whose implants were removed for various reasons, such as the presence of symptoms of rupture or other symptoms that could be due to implants, or for personal reasons. It is difficult to compare and interpret the results of these studies, since they do not always make a distinction between rupture, silicone bleed and silicone extravasation.

Mammography

Mammography is a relatively inexpensive and easily accessible radiological examination technique. A good number of women of various ages, some with and some without breast implants, are undergoing mammography in the Québec Breast Cancer Screening Program or, outside this program, for diagnostic purposes. Mammography is very sensitive in detecting extracapsular ruptures, which account for 10 to 20% of all ruptures, but it is not very sensitive in detecting intracapsular ruptures, which are more frequent and clinically silent. With a specificity of 97%, mammography yields few false-positive results and thus poses a smaller risk of unnecessary implant removal. It does pose a small risk of ionizing radiation exposure, especially in young women, but this risk is very small, thanks to the new techniques being used. The possibility of an implant rupturing due to breast compression has not been demonstrated, although this could happen with implants with preexisting defects.

Ultrasonography

Ultrasonography is a relatively inexpensive and easily accessible examination technique. It has an average sensitivity of 55% (range: 25 to 100%, depending on the study) and an average specificity of 77% (range: 50 to 92%, depending on the report). Ultrasonography can detect both intracapsular and extracapsular ruptures. Rupture detectability depends on the operator's experience and the instrument's technical quality. Ultrasound does not involve any type of radiation. Hence, there is no associated risk for women.

Magnetic resonance imaging

MRI is a sensitive (average of 77%) and specific (average of 94%) examination technique. It has the ability to detect both intracapsular and extracapsular ruptures. However, it is expensive and time-consuming. The fact that the scanners are less accessible and the resulting long waiting lists are major obstacles to the broader use of MRI. MRI requires the use of breast coils, which are dedicated surface coils. The use of this exploratory technique is contraindicated in women with a pacemaker, an aneurysm clip or other metallic foreign object and in women with claustrophobia.

Choice of technique

Based on the results presented and on the recommendations by several organizations and authors, systematic breast implant rupture screening cannot be recommended. In certain cases, a clinical examination performed by an experienced physician may suffice to determine if a defective implant should be removed. The use of detection techniques should be limited to cases where an implant is presumed to have ruptured. The technique of choice should be that with the best sensitivity (so that true cases of rupture are not missed) and the best specificity (to avoid false positives and unnecessary removal). However, other factors need to be considered, such as the cost of the examination, the availability of the technology in the community, the experience of the professionals who will be performing and interpreting the examination, and the technique's complications and limitations. It is also important to note the lack of consensus regarding the indication for removal in cases of intracapsular rupture and the adverse esthetic consequences of removing an implant.

Given the foregoing and the current state of knowledge regarding the efficacy of techniques for evaluating breast implant integrity, mammography and ultrasonography should be performed first when there are clinical signs or a presumption of breast implant rupture. MRI should be used to confirm the diagnosis when the mammography and ultrasonography results are equivocal or suspicious or when they do not agree with the findings of the clinical examination.

CONCLUSIONS AND RECOMMENDATION

In light of the scientific data examined in this report, AETMIS draws the following conclusions:

CONCLUSIONS

- The current state of knowledge reveals a lack of scientific data demonstrating the toxicity of silicone breast implants or the adverse health effects of silicone in women. This said, breast implant rupture is a local complication that has mainly esthetic consequences. However, if silicone turns out to be toxic to women, research should focus on the very use of breast implants rather than on implant rupture, for it is recognized that silicone migrates by sweating, even from intact implants, and that an implant shell is a source of silicone exposure.
- For now, published study reports do not provide explicit justification for setting up a program for implant rupture screening in asymptomatic women, since most of these studies involved women in whom the likelihood of rupture was high.
- Few studies have examined the role of mammography in iatrogenic implant rupture. The compression required during mammography could exacerbate a preexisting defect or cause an intracapsular rupture to become extracapsular, without constituting the primary cause of the rupture.
- The utility of MRI seems to reside in better detection of intracapsular rupture. However, such ruptures are generally asymptomatic, and there is no consensus regarding the indication for removal.
- Since MRI is slightly less specific than mammography in detecting extracapsular rupture, its use could result in the removal of intact implants. Yet, the risks and adverse esthetic consequences of this procedure could be worse than those associated with keeping the implant in place, despite an intracapsular rupture.

- MRI is an expensive technique, and in Québec, time on the waiting list for MRI is at least one year. On the other hand, mammography and ultrasonography are accessible screening tools and are already being used by the vast majority of the women in the Québec Breast Cancer Screening Program or, outside this program, for diagnostic purposes.

RECOMMENDATION

- Given the data on the efficacy and accessibility of the different techniques, AETMIS believes that, if there is a clinical presumption of rupture, the course of action should be modeled on the one which is detailed in the algorithm proposed by Samuels and colleagues and which is embraced by the IOM. A mammographic examination followed by a breast ultrasound is the recommended strategy of first recourse. If the results of these two examinations are normal, it is advisable to provide a clinical follow-up. If either of these examinations reveals an extracapsular rupture, the implant is removed. If the results of these examinations reveal an intracapsular rupture, some women may choose to keep their implants and to undergo a periodic clinical follow-up. Lastly, if the results are equivocal or suspicious or do not agree with the findings of the clinical examination, MRI is performed.

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EVALUATING THE VALIDITY OF A TEST[1]

The purpose of this section is to explain a few concepts that are essential to understanding this report. We present here the method for evaluating the internal validity of a test, i.e., the ability to detect or confirm a disease or some other undesirable condition by means of the test. In the present case, the object of the test is breast implant rupture.

		Implant		
		Ruptured	Intact	Total
Test result	+	TP	FP	TP + FP
	-	FN	TN	FN + TN
Total		TP + FN	TN + FP	TP + FP + TN + FN

TP: True-positive result (the implant is ruptured, and the test result is positive)
FP: False-positive result (the implant is intact, but the test result is positive)
FN: False-negative result (the implant is ruptured, but the test result is negative)
TN: True-negative result (the implant is intact, and the test result is negative)

- ***Sensitivity***: $\frac{VP}{VP + FN} \times 100$

  The ***sensitivity*** of a test is the proportion of implants that are actually ruptured for which the test result is positive.

- ***Specificity***: $\frac{VN}{VN + FP} \times 100$

  The ***specificity*** of a test is the proportion of intact implants for which the test result is negative. Its complement, ***1 - specificity***, is the ***proportion of false-positive results***. In this report, the complement of specificity is used to determine the number of intact implants that will be considered ruptured and is referred to as the ***false-positive rate***.

- ***Positive predictive value (PPV)***: $\frac{VP}{VP + FP} \times 100$

[1] The reference for this section is [Jenicek, 1995].

The ***positive predictive value*** of a test refers to the probability of actually having the undesirable condition when the test result is positive. In this report, this value is the proportion of ruptured implants for which the test result is positive.

- ***Negative predictive value (NPV)***: $\frac{VN}{VN + FN} \times 100$

The ***negative predictive value*** of a test is the probability of not having the undesirable condition when the test result is negative. In this report, this value is the proportion of intact implants for which the test result is negative.

- ***Accuracy (A)***: $\frac{VP + VN}{VP + FP + VN + FN} \times 100$

Accuracy refers to the proportion of true results, both positive and negative, among all the results obtained.

1. INTRODUCTION

Breast implantation has become increasingly common since the early 1960s. This surgical procedure meets the following two major needs: breast reconstruction following the ablation of a cancerous breast or an accident, or to correct a congenital malformation (breast aplasia, hypoplasia or asymmetry), and breast augmentation for cosmetic reasons. Breast implants or prostheses can be placed behind the mammary gland or the underlying pectoral muscle [Health Canada, 1998]. The terms *implant* and *prosthesis* are used synonymously in this report.

Up until 1991, most of the breast implants used were made of silicone gel covered with a polydimethylsiloxane shell. Although the scientific data do not show silicone to be toxic, the concerns raised by potential health risks led to the voluntary withdrawal of these products from the market in April 1991 and the adoption of a moratorium on the use of all silicone implants in Canada and the United States. The moratorium, which was declared in 1992, is still in effect [Health Canada, 1998].

Silicone gel breast implants have been associated with local and systemic complications and with an overall deterioration in health. Some of the local complications include pain, silicone gel bleed, implant rupture or capsular contracture. The systemic complications include the development of certain types of cancer (carcinoma of the breast or other organs, sarcomas, lymphomas, myelomas), autoimmune diseases and connective tissue diseases (lupus, scleroderma, rheumatoid arthritis, Gougerot-Sjögren syndrome) [ANDEM, 1996; Health Canada, 1998].

These problems are associated with the very presence of the implant and with its lifespan, in other words, with the probability of the shell rupturing over time and consequently of exposure of the body to silicone gel. The following techniques have been proposed in order to confirm or rule out the presumption of silicone implant rupture: mammography, breast ultrasonography, computed tomography and MRI. Breast compression during mammography has been suggested as one of the possible causes of iatrogenic rupture. Also, there is an increasing body of data to the effect that the efficacy of this technique in detecting certain types of implant rupture is quite limited [Gorczyca et al., 1997].

This report stems from a request made by the Minister of Health and Social Services to the Conseil d'évaluation des technologies de la santé, which was renamed, on June 28, 2000, as the *Agence d'évaluation des technologies et des modes d'intervention en santé*. This report assesses the efficacy of mammographic techniques in detecting implant rupture and silicone gel leakage, and the potential risks associated with these techniques, in order to determine if these risks warrant the use of an alternative imaging technique, such as MRI. Its authors also took into consideration the current medicolegal context and the climate of uncertainty regarding the validity of the links between autoimmune diseases and the presence of silicone gel outside a breast prosthesis.

The methodology used in this report is presented in Chapter 2. Chapter 3 briefly describes the various types of breast implants. Chapter 4 examines the problem of breast implant integrity, specifically, the types and frequency of ruptures. The efficacy, advantages and limitations of the various techniques for assessing implant integrity are examined in Chapter 5, which also looks at the diagnosing of breast cancer in women with breast implants. Chapter 6 summarizes the current knowledge regarding the toxicity of silicone, and Chapter 7 provides an overview of the positions of the various institutions concerned, both in Canada and elsewhere, regarding implant rupture detection. The situation in Québec, specifically, the regulatory and legal context, the extent and a description of the practice, is covered in Chapter 8. Lastly, Chapter 9 is a discussion of the results. This is followed, in Chapter 10, by conclusions and recommendations.

2. METHODOLOGY

In 1996, the Agence Nationale d'Accréditation et d'Évaluation en Santé, formerly the Agence Nationale pour le Développement de l'Évaluation Médicale (ANDEM), published an assessment report on silicone gel-filled breast implants in France. The report includes a systematic examination of the literature dealing with the methods for diagnosing the mechanical complications of implants [ANDEM, 1996]. A group of independent researchers in the United Kingdom, the Independent Review Group (IRG), examined the existing scientific data on silicone gel breast implants and submitted its report to the Department of Health in 1998 [IRG, 1998].

In 1997, the U.S. Congress asked the Department of Health and Human Services to fund an exhaustive study of the safety of silicone gel breast implants. A 13-member multidisciplinary committee under the Institute of Medicine (IOM) thus analyzed more than 3,400 English-language publications, some 2,300 articles published in peer-reviewed journals and 1,100 items such as technical reports, books, letters, opinion articles, position statements and abstracts) on breast implants and produced a preliminary report. The latter was then given to 11 experts acting as external reviewers. The final version of the report was published in June 2000 by the IOM. It contains many important conclusions regarding silicone gel implant rupture [IOM, 2000]. The recentness of the three reports thus produced, the extent and quality of the resources used to prepare them, the exhaustiveness of the studies examined and the rigour of the analyses that were performed guarantee the validity of these organizations' conclusions. This is why the conclusions in the ANDEM, IRG and IOM reports form the core basis of the present assessment.

The IOM report is the most recent one and includes scientific data published up until 1998. We therefore did an update in order to include data published since then (from January 1999 to August 2001), by querying various databases (MEDLINE, Cochrane, Embase, Pascal and HISTAR) using the following keywords: "breast" in combination with "implant" or "implantable" or "implantation" or "implants". Other papers were identified in lists of references in reviews and in lists in *Current*

Contents. These data were updated on a regular basis and supplemented with Internet searches. We studied in detail all the articles dealing with the detection of silicone implant rupture found in the databases and those that were cited in the ANDEM and IOM reports, in order to extract the data that are presented in this report. By consulting health professionals, we documented various aspects of the situation in Québec regarding silicone gel breast implants.

Unless otherwise indicated, when the data presented in this report were taken from the IOM report [IOM, 2000], we refer the reader to that report rather than to one of the specific studies cited and analyzed in it.

3. TYPES OF BREAST IMPLANTS

Breast implants come in a wide variety of shapes, volumes (80 to 1,000 cm^3) and sizes (7.5 to 16.8 cm in diameter and 1.5 to 7.5 cm thick) [IOM, 2000]. The United States produces more than 240 different models of breast implants made from various materials. Middleton and McNamara published a classification of breast implants based on historical considerations and diagnostic images (MRI) [Middleton and McNamara, 2000], which can be summarized as follows:

1) single-lumen silicone gel-filled
2) single-lumen silicone gel-saline adjustable, to which can be added a variable amount of saline at the time of placement.
3) single-lumen saline-, dextran (glucose solution)- or PVP (polyvinyl pyrrolodone)-filled.
4) standard double-lumen, silicone gel in the inner compartment and saline in the outer compartment.
5) double-lumen, saline in the inner compartment and silicone gel in the outer compartment.
6) adjustable double-lumen, silicone gel in both compartments, to which a variable amount of saline can be added in the inner compartment at the time of placement.
7) double-lumen, silicone gel in both compartments.
8) triple-lumen, silicone gel in the inner and middle compartments and saline in the outer compartment.

Other, much less common types of implants include the Cavon "cast gel", or cohesive silicone gel with no shell; the custom, nonstandard implant; the soft pectus, a solid silicone elastomer pectoralis muscle replacement implant; the nonadjustable sponge; the adjustable sponge with a silicone elastomer shell (polyurethane-coated); the saline- or dextran-filled polyurethane sponge; and other implants filled with triglycerides or other substances not mentioned above.

Most of the prosthesis seen by Middleton and McNamara were single-lumen silicone gel implants (79.6%) or standard double-lumen implants with a silicone-filled inner compartment and a saline-filled

outer compartment (11.1%). There were other single-lumen implants (6.2%), which were saline-, dextran (glucose solution)- or PVP (polyvinyl pyrrolodone)-filled [Middleton and McNamara, 2000]. Breast prostheses have evolved in response to the problems observed during use. The first commercially available implant with a leakproof shell contained silicone gel. It was manufactured by Dow-Corning. The first implantation was performed in 1962. Previously, since the 1950s, silicone was injected directly into the breast. As for the first saline-filled implant, it was created in 1965 by Simaplast.

The polyurethane foam-coated shell was very popular. However, in a physiological environment, polyurethane undergoes chemical breakdown and releases certain compounds (2,4-toluenediamine [2,4-TDA] or its precursors), which can be carcinogenic in animals, although this effect has not been observed in humans. Infectious complications have also been attributed to it. Furthermore, the polyurethane coating was opaque on mammograms and hindered rupture detection by MRI. These implants were discontinued in 1991. Other implants have a silicone elastomer shell with a special texture aimed at minimizing capsular contracture. Other materials have been used in the manufacture of implant shells in an effort to reduce the spread of silicone compounds into the tissues [IOM, 2000].

As for the contents of implants, the most popular ones are filled with silicone gel and saline. Saline implants were quickly discontinued after they were put on the market in 1965, because of their tendency to deflate and because of the more natural consistency and texture of silicone implants [ANDEM, 1996; Watson et al., 1997]. In May 2000, the Food and Drug Administration (FDA) approved the marketing of new saline-filled implants manufactured by two different companies, despite the fact that the use of such implants has been associated with local and systemic complications similar to those previously caused by silicone implants [Zuckerman et al., 2000]. All the other implants of this type are considered experimental [FDA, 2000].

The other avenues presently being explored basically concern the use of hydrogel and triglycerides. The hydrogel used in breast implants consists of polysaccharides similar to cellulose and are therefore nonbiodegradable in the body. The triglycerides are vegetable oils, mainly soy, which are biodegradable in the body [Watson et al., 1997]. In June 2000, the British counterpart of the FDA, the Medical Devices Agency (MDA), published recommendations aimed at women with breast implants filled with purified soy oil (Trilucent®). Because of new data showing a toxicological risk, the MDA urged these women to consult their physician with a view to having the implants removed and advised them against becoming pregnant and breast-feeding as long as the implants were still in place [MDA, 2000].

4. BREAST IMPLANT INTEGRITY

4.1 Types of rupture

Prosthetic rupture occurs upon a tear in the implant shell, which results in the extravasation of the silicone gel into the capsule (intracapsular rupture) or into the surrounding tissues (extracapsular rupture) [ANDEM, 1996]. The capsule is the isolating fibrous membrane that forms following a fibrous or inflammatory reaction in the body to the presence of the silicone shell covering the implant. The capsule plays an important double role in implant rupture. First, its contracture results in a painful syndrome, which can be relieved by performing a closed capsulotomy. This consists in compressing the contracted capsule by external maneuvers in order to break it. These maneuvers and the exerted pressure can cause the implant to rupture. Second, the capsule serves to isolate or confine any free silicone in the event of an intracapsular implant rupture [ANDEM, 1996].

A loss of implant integrity can result from the complete rupture of the shell, a break in the continuity of the shell or from the bleeding of the contents through an intact shell. If the capsule is intact, the silicone will be contained and the rupture will generally be asymptomatic and undetectable on clinical examination or mammography, without any breast deformity. This is referred to as an *intracapsular* rupture. The FDA and most plastic surgeons recommend removing the implant in all cases of rupture, whether intracapsular or extracapsular, because of the risk of an intracapsular rupture becoming extracapsular and of the possibility of silicone spreading into the surrounding tissues [FDA, 2000]. In practice, there is no general agreement as to the indication for explantation in the event of intracapsular rupture, and this type of rupture does not necessarily lead to surgical removal, especially if the patient wishes to keep the implant and agrees to a more regular follow-up[2]. In Denmark, there are no formal recommendations in this regard, and the debate continues among plastic surgeons [Hölmich et al., 2001].

If the capsule loses its integrity, the silicone gel can migrate into the breast tissues or to distant points in the chest cavity, the upper limbs or the pelvic region. The distant migration of silicone is an extremely rare complication. This type of rupture, referred to as *extracapsular*, constitutes an indication for removal. Implants containing saline can rupture as well, but the physiological solution is quickly absorbed by the tissues without causing any systemic complications. In such case, the local complication is breast deformity, which manifests as a loss of esthetics [IOM, 2000].

It should be noted that the bleeding of silicone through an intact shell is the equivalent of an implant rupture, for the leakage of silicone outside the shell would result in the same complications as a shell rupture.

[2] Personal communication with Dr. Duranceau, plastic and cosmetic surgeon, in October 2000.

4.2 Prevalence and probable causes of rupture

Based on its analysis of the results of 29 scientific studies, the IOM reports implant rupture rates ranging from 0.3 to 77%. These rates indicate the percentage of women in whom one or two implants ruptured or the percentage of all the implanted prostheses that ruptured. All methods for reviewing data on the frequency of breast implant rupture lack accuracy. When these data are from observations recorded upon explantation, they can include a certain number of prostheses damaged during the intervention. Furthermore, the case series based on rupture detection by various diagnostic methods, such as the clinical examination or mammography, can be taken from data concerning surgical removal or include groups of patients in whom the presumption of rupture had been made on clinical examination or by other exploratory techniques. Lastly, the reported rupture rates based on surveys of the manufacturers are very low. These rates, which are based on returns, complaints and lawsuits, are probably biased because of underreporting [IOM, 2000].

The prevalence of implant rupture seems to vary with the age and generation of the implant. Peters and collaborators, who are cited in the IOM report, examined 352 implants that were surgically removed. They did not observe any ruptures in the first-generation implants (marketed from 1963 to 1972) but found the second-generation implants (marketed from 1972 to the mid-1980s) to be 95% ruptured at 12 years after placement and 3.5% of the third-generation implants (used from the late 1980s to 1996) to be ruptured by 1992 [Peters et al., 1996]. According to the observations made, again by Peters, upon the removal of 28 first-generation implants, 96.4% of them were intact. The age of the implants varied from 14 to 28 years (mean age of 20.8 years). The rupture rate is much higher in second-generation implants, and it cannot yet be determined for third-generation implants [Peters, 2000].

Based on a cautious evaluation by the IOM committee, the percentage of modern silicone gel implants that will have ruptured by five years after placement is modest (less than 10%) and will increase in ensuing years [IOM, 2000].

Benadiba and colleagues studied the lifespan of breast implants used in breast reconstruction following cancer surgery [Benadiba et al., 2000]. They followed 596 patients (949 implants) for 8 years (range: 2 to 14 years). They found that the overall median lifespan of the implants was 127 months, or about 10 years. The median life span of the silicone gel implants was slightly longer (less than 12 years) than that of the saline-filled implants (less than 10 years). Of the 639 inflatable implants, 83 (13%) deflated, and 77 of these were reoperated on. In 73 implants, the shell was ruptured, but it was intact in 4 others, which had a defective valve. Of the 306 silicone gel-filled implants, 5 (1.6%) were ruptured. One half of the implants were intact 10 years after placement [Benadiba et al., 2000]. Robinson and colleagues [1995] examined the implant survival curve in 300 women and also concluded that only 51% and 4.6% of the implants were intact 12 and 20 years, respectively, after placement [Robinson et al., 1995].

The FDA recently completed an observational study of silicone gel breast implant rupture. There were two parts to the study: a telephone interview survey of 907 women and an MRI examination of 344 women with silicone gel implants. One third of the participants in the survey (303/907) reported that they had undergone at least one surgical intervention during which the implant was removed or replaced. Seventy-three women (73/303) reported that the surgery was performed because of symptoms (breast pain, chest pain or upper body pain) or signs (change in breast shape) of rupture. The survey revealed that implant rupture had, in fact, occurred in 171 of the 303 women who had undergone surgery. However, a chart review did not permit confirmation of rupture in all the cases [Brown and Pennello, 2000].

In the second part of the study, an MRI examination was performed in 344 women (80% of the 445 women invited to participate) selected whether or not there were signs and symptoms of prosthesis rupture. In all, 687 implants were examined by MRI (82% of the implants were single-lumen silicone gel prostheses; the others were double-lumen saline-gel implants). Three radiologists independently examined the images in order to give their assessment of the implants' integrity and the possibility or presence of a rupture. At least two of the three radiologists detected a rupture in 55% of the implants (378/687), or in 69% of the women (237/344). The detected rupture was extracapsular in 85 of the 687 implants examined (12%), or in 21% of the women (73/344) [Brown et al., 2000].

Breast compression during mammography has been suggested as a possible iatrogenic cause of implant rupture, but few studies have examined this matter. In a study of 1,619 implants, the investigators Feng and Amini did not observe a significant link between the compression required during mammography and implant rupture [Feng and Amini, 1999]. Middleton believes that mammography very rarely causes rupture but that it could worsen a preexisting defect or cause an intracapsular rupture to become extracapsular [Middleton, 1998]. It has also been suggested that direct trauma and closed capsulotomy might be factors for traumatic implant ruptures. However, the results of Feng and Amini's study indicate that factors relating to implants themselves and to patients play a greater determining role than trauma-related factors in implant rupture. Some of the nontrauma-related factors associated with implant rupture include implant age, manufacturing defects, shell quality and the implant’s location, i.e., whether it is subglandular or subpectoral [ANDEM, 1996; Brown et al., 2000; Feng and Amini, 1999].

5. Breast implants and breast imaging

In this section, we examine the following two aspects, which bring together breast imaging and breast implants: assessing implant integrity (detecting ruptures and bleed) and diagnosing breast cancer and other breast diseases in women with breast implants.

5.1 Assessing implant integrity

Implant rupture is defined as the presence of a detectable quantity of silicone gel outside the implant or periprosthetic capsule. A distinction should be made between rupture and gel diffusion or bleed, i.e., the passing of liquid silicone through an intact shell into the capsule or the surrounding breast tissues. In an intracapsular rupture, the silicone gel remains contained within the capsule, while in an extracapsular rupture, it spreads into the surrounding breast tissues. The prevalence of rupture has not been accurately determined. The current detection methods are a clinical evaluation and diagnostic examinations, including mammography, computed tomography, ultrasonography and MRI [IOM, 2000]. When performed by an experienced physician, a clinical examination can, in certain cases, suffice to determine the appropriateness of surgically removing an implant that has suffered a loss of integrity. The type of prosthesis and the year of its placement are indicators that can guide the clinical decision. Indeed, the fragility of second-generation implants, which were put on the market in 1972 and whose wall is very thin, is well established. On the other hand, mammographic images can lead one to conclude that certain very supple prostheses have ruptured when they are actually intact.

Computed tomography is almost never used, since it carries more risks than it offers advantages, due to the radiation exposure that it requires. Most women with breast implants are young and have chosen to use them for esthetic reasons. For this reason, this technique will not be assessed in this report.

The studies examined are for the most part case series. In general, the series were small and mainly included women whose implants were removed for various reasons, such as the presence of symptoms of rupture or other physical symptoms that could be due to implants, or because of personal health concerns that led to the desire to have the implants removed. We chose those studies in which the reference test was surgical intervention and for which it was possible to obtain or ascertain 1) the number of implants examined; 2) the number of implants in which rupture was confirmed on surgical removal; 3) the necessary data for calculating the test's sensitivity, specificity and accuracy.

5.1.1 Mammography

Mammography is an examination technique widely used in screening for and diagnosing breast diseases. In the presence of a breast implant, one should follow a protocol involving four views of each breast, specifically, after the implant is pushed back (Eklund technique), in order to clearly visualize the mammary parenchyma. The normal image of an implant depends on the type of implant and its exact seat. The image of a silicone gel implant is normally radio-opaque, oval and homogeneous, and its margin is smooth and well defined. Saline-filled implants are less radio-opaque. As for double-lumen implants, their images reveal the less opaque saline layer that covers the more opaque silicone [O'Toole and Caskey, 2000].

Signs of rupture or bleed

In double-lumen implants, the leakage of saline from the outer compartment is revealed on mammography by the absence of opacity where it would otherwise be expected. The image obtained is similar to that of a single-lumen silicone gel implant. If it is the internal lumen that has ruptured, the mixture of the contents of the two compartments yields characteristic mammographic images. However, if the saline-to-silicone ratio is low, the image will be identical to that of a single-lumen implant or to that of a saline leak contained in the outer compartment [Monticciolo, 1997].

Intracapsular ruptures cannot be easily detected by mammography. On mammography, the signs of extracapsular rupture of a silicone gel implant are the visible presence of free silicone in the surrounding tissues and a change in the implant's size or shape. The fact of detecting silicone in the breast tissues or even in the lymph nodes is not always a sign of implant rupture, since silicone, which diffuses through an intact shell, can also accumulate in the surrounding tissues or migrate into the lymphatic system. When an implant ruptures, the silicone migrates toward the areas of least resistance, generally the axilla. However, the extension of an implant into the axillary region can result from herniation of an intact prosthesis through a ruptured fibrous capsule or weakness in an intact capsule rather than a rupture, in which case the differential diagnosis is difficult to make [Monticciolo, 1997; O'Toole and Caskey, 2000].

Sensitivity and specificity

The use of mammography for the specific purpose of detecting breast implant rupture has not been examined in in-depth studies. Based on an analysis of the results of six studies, the sensitivity of this technique in detecting ruptures varies from 5 to 81%, with a specificity of 82 to 100% (Table 1). The wide range in sensitivity is due to the inability to detect intracapsular ruptures, which account for 80 to 90% of silicone gel implant ruptures [Azavedo and Boné, 1999; Gorczyca et al., 1997]. The studies that report the lowest sensitivity are characterized by a higher proportion of intracapsular ruptures [Netscher et al., 1996].

The studies in which the type of rupture is specified report a sensitivity of 100% in detecting extracapsular ruptures. However, this figure should be interpreted with caution because of the small number of extracapsular ruptures that were observed in these studies, mainly because of this type of rupture has a low prevalence. Furthermore, mammography is of very limited diagnostic utility for assessing posterior implant wall integrity [Monticciolo, 1997].

Table 1. Sensitivity, specificity and accuracy of mammography in detecting prosthetic rupture

Study	Design	Number of implants examined	Number of ruptures surgically confirmed				Sensitivity(%) (actual numbers)	Specificity (%) (actual numbers)	A (%)
			EC	IC	B	T			
Everson et al., 1994	P	63	1	21	0	22	23 (5/22)	98 (40/41)	71
Monticciolo et al., 1994	P	34	ns	ns	ns	16	81 (13/16)	100 (18/18)	91
Reynolds et al., 1994	P	24	ns	ns	ns	13	69 (9/13)	82 (9/11)	75
Robinson et al., 1995	P	133	ns	ns	ns	83	17 (14/83)	92 (46/50)	45
Netscher et al., 1996	P	160	2	40	0	42	5 (2/42)	100 (118/118)	75
Ikeda et al., 1999	P	31	4	9	5	18	33 (6/18)	100 (13/13)	61
Total		445				194	25 (49/194)	97 (244/251)	66

P: prospective; A: accuracy; EC: extracapsular rupture; IC: intracapsular rupture; B: bleed; T: total number of ruptures; ns: not specified.
All the studies (authors indicated in **bold**) involved a comparison of two or three imaging techniques.

On average, the sensitivity of mammography in detecting rupture is 25%, with 97% specificity. When all of the studies are considered together, the positive predictive value of mammography is 88% (49/56), its negative predictive value 63% (244/389).

Advantages and limitations

Mammography is a relatively inexpensive technique, and many women of different ages are undergoing mammography in the Québec Breast Cancer Screening Program or, outside this program, for diagnostic purposes. It is very sensitive in detecting extracapsular rupture, which is a formal indication for explantation.

Mammography is not very sensitive in detecting intracapsular ruptures. Yet, between 80 and 90% of implant ruptures are of this type. Furthermore, the breast compression required during mammography could cause an implant to rupture or damage the capsule and cause conversion of intra- to extracapsular rupture, with resulting migration of silicone gel into the body. However, these complications are mainly isolated events that could affect implants which are more vulnerable because of other factors, such as age or previous trauma [Azavedo and Boné, 1999; Gorczyca et al., 1997].

Mammography also carries a risk associated with the irradiation of a radiosensitive tissue like breast tissue. While the dose of radiation may be acceptable in the context of breast cancer screening or diagnosis, it would not, perhaps, be so in the case of breast implant rupture screening, all the more so

because such screening is carried out mainly in young women [ANDEM, 1996]. It should be noted that the dose of radiation emitted by the mammography machines currently in use (less than 0.1 cGy or rad per view) is comparable to that received during a chest x-ray and reportedly involves a negligible risk in the framework of breast implant rupture screening. The advantages and limitations of mammography in detecting breast implant rupture are summarized in Table 2.

Table 2. Summary table on mammography for assessing breast implant integrity: advantages and limitations of the test

Advantages	Limitations
Rapid and inexpensive.	Risk associated with irradiation (should be considered only in the context of implant rupture screening).
Currently performed on many women of different ages in the QBCSP or for diagnostic purposes.	Low sensitivity, risk of false-negative result, that is, of considering a ruptured implant intact.
Very sensitive in detecting extracapsular ruptures.	Poor ability to detect intracapsular ruptures, which are more frequent but often clinically silent.
Good specificity, low false-positive rate and therefore a lower risk of unnecessary removal.	Low sensitivity in examining the posterior wall of an implant.
	Potential cause of intracapsular or extracapsular rupture because of the compression of the breast.

5.1.2 Ultrasonography

Ultrasonography is used routinely as an adjunct to mammography for evaluating palpable or clinically occult breast masses, architectural changes and asymmetrical density, but assessing the integrity of an implant requires a more thorough examination. A normal ultrasound image varies according to the type of implant. In general, it shows an anechogenic triangular structure whose anterior echogenic line represents the shell or capsule. The variable thickness of this line is due to reverberation artifacts. It is difficult to distinguish images of saline implants from images of silicone gel implants, except when one sees the filling valve of the saline implant [O'Toole and Caskey, 2000].

Signs of rupture or bleed

In the case of an intracapsular rupture or implant bleed, a sonogram will reveal the presence of various signs, such as parallel echogenic lines of variable length (stepladder sign), internal implant echo heterogeneity and echogenic bands across the implant. The presence of free extracapsular silicone is manifested by the dispersion of the ultrasound beam (snowstorm), with or without a hypoechogenic mass. Other, less specific signs include implant deformity, a break in the continuity of the shell, and the presence of fluid around the prosthesis [Harris, 1997].

Sensitivity and specificity

Based on an analysis of 14 studies aimed at assessing the diagnostic value of ultrasonography in cases of rupture, this exploratory technique has a mean sensitivity of 56% (range: 25 to 100%), with a mean specificity of 77% (range: 50 to 92%). Ultrasound is more specific than it is sensitive in detecting breast implant rupture, and its sensitivity seems to be greater in the absence of capsular contracture (Table 3) [ANDEM, 1996; IOM, 2000; Medot et al., 1997]. Furthermore, the lowest sensitivity values are from studies in which cases of silicone bleed were included in the calculation [Berg et al., 1995; Chilcote et al., 1994].

When all of the 1,038 cases in the 14 studies analyzed are considered together, the positive predictive value of ultrasound is 60% (221/368), its negative predictive value 73% (489/670).

Table 3. Sensitivity, specificity and accuracy of ultrasonography in detecting prosthetic rupture

Study	Design	Number of implants examined	Number of ruptures surgically confirmed				Sensitivity (%) (actual numbers)	Specificity (%) (actual numbers)	A (%)
			EC	IC	B	T			
DeBruhl et al., 1993	P	57	4	16	0	20	70 (14/20)	92 (34/37)	84
Caskey et al., 1994	P	59	1	21	0	22	55 (12/22)	84 (31/37)	73
Chilcote et al., 1994	P	42	0	7	13	20	25 (5/20)	75* (16/22)	50
Everson et al., 1994	P	61	1	21	0	22	59 (13/22)	79 (31/39)	72
Liston et al., 1994	P	43	ns	ns	ns	13	69 (9/13)	96 (27/28)	88
Petro et al., 1994	P	22	ns	ns	ns	7	100 (7/7)	-	-
Reynolds et al., 1994	P	24	ns	ns	ns	13	54 (7/13)	64 (7/11)	58
Berg et al., 1995	P	144							
Single-lumen			4	36	28	68	49 (33/68)	57 (31/54)	52
Double-lumen						22	8 (1/12)	20 (2/10)	14
Weizer et al., 1995	P	143	ns	ns	ns	38	47 (18/38)	83 (87/105)	73
Chung et al., 1996	P	192	ns	ns	ns	62	74 (46/62)	89 (116/130)	84
Venta et al., 1996	P	78	ns	ns	ns	22	50 (11/22)	55 (31/56)	54
Medot et al., 1997	R	122	ns	ns	ns	49	59 (29/49)	73 (53/73)	67
Without capsular contracture		85				32	69 (22/32)	74 (39/53)	72
With capsular contracture		37				17	41 (7/17)	70 (14/20)	57
Ikeda et al., 1999	P	31	4	9	5	18	67 (12/18)	62 (8/13)	65
Beekman et al., 1999	P	35	0	16	0	16	44 (7/16)	84 (16/19)	66
Total		1,053				402	56 (224/402)	77 (490/634)	69

P: prospective; R: retrospective; A: accuracy; EC: extracapsular rupture; IC: intracapsular rupture; B: bleed; T: total number of ruptures; ns: not specified.

The studies whose authors appear in ***italics*** and **bold** involved a comparison of two or three imaging techniques.

* Figure provided by the authors, being a mean of the results obtained by the four sonographers. The figure of 16 is the approximate value of this mean.

Advantages and limitations

As an examination technique, ultrasonography is less expensive than MRI and computed tomography. Unlike mammography machines and CT scanners, ultrasound scanners do not emit any ionizing radiation [Harris, 1997]. A complete examination of both breasts by an experienced operator can take 15 minutes. Ultrasound is capable of detecting very small quantities of silicone outside an implant and an intracapsular rupture. It is especially useful when MRI is contraindicated (claustrophobia, pacemaker, aneurysm clip) [Azavedo and Boné, 1999; Gorczyca et al., 1997].

The results of an ultrasound examination depend on the sonographer's experience, both in performing

such examinations and in interpreting their results, and they are less reproducible than MRI results, for a sonographer interprets images in real time. However, he/she can only record static images [Harris, 1997]. Also, the technique used can affect the efficacy of this examination modality [Azavedo and Boné, 1999; IOM, 2000].

The advantages and limitations of ultrasonography in detecting breast implant rupture are summarized in Table 4.

Table 4. Summary table on ultrasonography in the assessment of breast implant integrity: advantages and limitations of the test

Advantages	Limitations
Inexpensive. No radiation. Detects intracapsular and extracapsular ruptures. Useful when MRI is contraindicated.	Results depend on the operator and the technique used. Low sensitivity, hence a risk of false negatives. Lower specificity than mammography. Difficult to examine the posterior wall of an implant.

5.1.3 Magnetic resonance imaging

MRI is the most accurate method for detecting intracapsular and extracapsular ruptures. When performed with a high-resolution scanner that generates a magnetic field intensity of 1.5 tesla, MRI will provide very accurate images of the internal structure of an implant. The use of breast coils in women in the ventral decubitus position tends to result in good images of the mammary gland. MRI permits good visualization of the mammary parenchyma, the implant, the axillary region and the chest wall [O'Toole and Caskey, 2000].

Signs of rupture or bleed

MRI detects intracapsular prosthetic rupture by revealing folded shell fragments or shell fragments floating inside the implant ("linguine" sign) and free silicone in the mammary parenchyma (Gorczyca et al., 1997]. Bleed manifests as the "teardrop" sign, caused by a teardrop-shaped fold on the periphery of the implant, and, in the case of extracapsular ruptures, MRI is capable of detecting silicone leakage or the presence of a granuloma outside the fibrous capsule [Tardif-de Géry et al., 2000].

Sensitivity and specificity

We examined 13 studies on MRI. On average, when used to detect breast implant rupture, this technique has a sensitivity of 77% (range: 46 to 100%) and a specificity of 94% (range: 55 to 100%). A

summary of the results in the 13 published study reports concerning the diagnostic value of MRI in cases of prosthetic rupture are summarized in Table 5.

Table 5. Sensitivity, specificity and accuracy of MRI in detecting prosthetic rupture

Study	Design	Number of implants examined	Number of ruptures surgically confirmed				Sensitivity (%) (actual numbers)	Specificity (%) (actual numbers)	A (%)
			EC	IC	B	T			
Gorczyca et al., 1992	R	140	2	19	0	21	76 (16/21)	97 (116/119)	94
Dobke *et al.,* 1994	R	74	ns	ns	8	24	100 (24/24)	98 (49/50)	99
Everson et al., 1994	P	59	1	18	0	19	95 (18/19)	93 (37/40)	93
Gorczyca et al., 1994	R	81	2	16	0	18			
3-point Dixon							61 (11/18)	97 (61/63)	89
FSE							89 (16/18)	97 (61/63)	95
Monticciolo et al., 1994	P?	38	ns	ns	ns	18	94 (17/18)	100 (20/20)	97
Reynolds et al., 1994	P	24	ns	ns	ns	13	69 (9/13)	55 (6/11)	63
Berg et al., 1995	P								
Single-lumen		122	4	36	28	68	78 (53/68)	91 (49/54)	84
Double-lumen		22	ns	ns	ns	22	75 (9/12)	90 (9/10)	82
Robinson et al., 1995		10	ns	ns	ns	7	71 (5/7)	67 (2/3)	70
Weizer et al., 1995	P	160	ns	ns	ns	41	46 (19/41)	88 (105/119)	78
Quinn et al., 1996	P	108	1	29	0	30	87 (26/30)	78 (61/78)	81
Middleton, 1998	R	785	87	306	-	394	74 (292/394)	98 (385/391)	86
Beekman et al., 1999	P	35	0	16	0	16	88 (14/16)	100 (19/19)	94
Ikeda et al., 1999	P	31	4	9	5	18	100 (18/18)	77 (10/13)	90
Total		1,689				687	77 (536/699)	94 (929/990)	87

P: prospective; R: retrospective; A: accuracy; EC: extracapsular rupture; IC: intracapsular rupture; B: bleed; T: total number of ruptures; ns: not specified.

The studies whose authors appear in ***italics*** and **bold** involved a comparison of two or three imaging techniques.

The sensitivity and specificity of MRI increase when use is made of unilateral or bilateral breast coils, surface coils specially designed for breast examinations. When all of the 1,689 cases in the 13 studies examined are considered together, the positive predictive value of MRI is 90% (536/597), with a negative predictive value of 85% (99/1,092). A recently published meta-analysis confirms these figures. Upon combining the results of 18 studies, Cher and colleagues [2001] did, in fact, arrive at a sensitivity of 78% (95% CI: 71 to 83%) and a specificity of 91% (95% CI: 86 to 94%). The authors call attention to the studies' heterogeneity, which was due to the small sample sizes and their poor methodological quality. They conclude that MRI should be reserved for confirming cases where there is a moderate or

strong presumption of rupture [Cher et al., 2001].

Advantages and limitations

MRI is the most sensitive and specific technique for assessing breast implant integrity. It is capable of detecting both intracapsular and extracapsular ruptures but not the leakage of small quantities of silicone outside an implant. It can be used to examine the posterior wall of an implant and the tissues underlying the implant [Azavedo and Boné, 1999]. If breast coils are used and the type of implant and its characteristic images are known, interoperator agreement may be excellent [IOM, 2000].

MRI is an expensive and time-consuming examination technique. It requires the use of dedicated surface coils, the performance of specific test sequences and knowledge of the type of implant and its specific characteristics. Reduced accessibility to MRI scanners and the resulting long waiting lists are major obstacles to the more widespread use of this technology. MRI is contraindicated in women with a pacemaker, aneurysm clip or other metallic foreign objects. Furthermore, women with claustrophobia cannot tolerate MRI [Gorczyca et al., 1997]. A summary of the advantages and limitations of MRI in evaluating breast implant rupture is provided in Table 6.

Table 6. Summary table on MRI in the assessment of breast implant integrity: advantages and limitations of the test

Advantages	Limitations
No radiation. Very good sensitivity and specificity in detecting silicone breast implant rupture. Detection of intracapsular and extracapsular ruptures. More accurate determination of the extent of a rupture and, in particular, in cases of small leaks, of an intracapsular or extracapsular rupture. Good visualization, in all cases, of the entire prosthesis, especially its posterior wall.	Expensive and time-consuming. Low accessibility to scanners. Cannot detect the presence of small quantities of free silicone outside an implant. Requires the use of surface coils specially designed for breast examinations. Contraindications: pacemaker, aneurysm clips or other metallic foreign objects, and claustrophobia.

5.1.4 Comparison of the three techniques

The studies in which these three techniques were compared are mentioned in the previous sections, and the authors' names appear in italics in Tables 1, 3 and 5. A more detailed description of the studies' characteristics and results is provided in Tables A.1 and A.2 in Appendix A. The studies examined involved a parallel comparison of detection techniques. Each test's validity was calculated after surgical confirmation, in all cases, of the implant's status.

According to Monticciolo and colleagues, mammography has a sensitivity of 81%. The mammography and MRI results were concordant for 30 of the 34 implants that were examined. As for the remaining four implants, surgery confirmed three cases of rupture detected by MRI and one case detected by mammography [Monticciolo et al., 1994]. Therefore, by combining the two techniques, all the implant ruptures would have been correctly detected. The authors conclude that MRI can be useful in the presence of clinical signs of rupture when no signs of rupture are observed on the mammograms or when it is necessary to determine the extent of the rupture [Monticciolo et al., 1994]. Reynolds and collaborators [1994] compared the efficacy of the three detection techniques but did not determine any one of them to be superior to the other. In their opinion, the definition of the term *rupture* poses a problem, since it includes a broad spectrum of lesions ranging from minimal extravasation to the total disintegration of the shell with rupture of the capsule. Furthermore, the authors question the clinical value of a diagnosis of minimal extravasation, which apparently does not have more consequences for the patient than the normal diffusion of silicone through an intact shell [Reynolds et al., 1994].

Weizer and colleagues prospectively examined 143 implants by ultrasound and MRI [Weizer et al., 1995]. In their opinion, the low sensitivity and specificity of the results obtained with these two techniques was due to the implants' heterogeneity (74% of them were single-lumen and contained silicone, whereas the others were polyurethane-coated, saline-filled or double-lumen implants). If a rupture was confirmed when only one of the tests gave a positive result, that test's specificity was high (96.4%), but its sensitivity was low (47.8%). If a rupture was confirmed by a positive result with both tests, the sensitivity was 61.9%, the specificity 82.5%. This way of combining the tests should be explored more thoroughly in larger studies [Weizer et al., 1995]. Beekman and collaborators reported the results of examining, by mammography and ultrasound combined, 76 implants, including 39 cases of surgically confirmed intracapsular rupture [Beekman et al., 1996]. The sensitivity of these two techniques combined was 64%, their specificity 81%. Given that intracapsular rupture cannot be detected by mammography, these results are attributable mainly to ultrasound.

Ikeda and collaborators compared the accuracy of MRI, ultrasonography and mammography in assessing implant integrity in a prospective study of 59 implants and 30 women who had symptoms of implant rupture [Ikeda et al., 1999]. Each case had been evaluated by a plastic surgeon, but, for unknown reasons, surgical removal had not been performed in 14 of these cases (28 implants). Based on the MRI and ultrasound results, the implants were intact in 12 of these 14 cases, and both implants were ruptured in the other two cases. Because there were no surgical results corroborating the diagnostic imaging results, these 14 cases were excluded. The investigators were able to match the imaging results and the results of surgical exploration for 31 implants (16 women). In 13 cases, the implant was intact, and 5 other implants were intact as well, but there was severe silicone gel bleed, and 13 cases of rupture were confirmed upon surgery, with 9 intracapsular ruptures and 4 extracapsular ruptures. The mean age of the intact implants was 10 years, that of the ruptured implants 15 years. As for confirming breast implant rupture, MRI proved more accurate (81%) and sensitive (100%) than ultrasound (accuracy and sensitivity 65% and 67%, respectively) and mammography (61% and 33%, respectively). However, the three techniques correctly detected the four cases of extracapsular rupture. One of the five cases of severe gel bleed was correctly detected by mammography. In four cases, ultrasound permitted the conclusion that there was an extracapsular rupture, whereas MRI showed one of these cases to be severe gel bleed; two were cases of extracapsular rupture; and three were cases of intracapsular rupture. The specificity of mammography, ultrasonography and MRI were 100%, 62% and 77%, respectively [Ikeda et al., 1999].

Beekman and colleagues examined the preoperative diagnostic efficacy of MRI and ultrasound in the examination of 35 single-lumen silicone gel implants (18 women) [Beekman et al., 1999]. The mean age of the implants was 16 years (range: 4 to 22 years). The decision to remove the implants had been made before MRI and ultrasound were performed. No extracapsular ruptures were detected after surgery, and the implants that were bleeding were considered intact. In this study, the sensitivity of ultrasonography was found to be 44%, its specificity 84%. The positive predictive value (PPV) and negative predictive value (NPV) of ultrasound were 70% and 64%, respectively. The accuracy of this

test was 66%. MRI proved to be more sensitive (88%) and more specific (100%) than ultrasound. The predictive values for MRI were higher as well (PPV = 100%, NPV = 90%), and this test's accuracy was found to be 94%. The authors conclude that MRI should be considered the standard technique for confirming silicone breast implant rupture.

The examination technique of choice should be the one with the greatest sensitivity and specificity and the best predictive value. However, other factors need to be taken into consideration, such as the cost of the test, accessibility to the technology within the community, the experience of professionals who will be performing the examination and interpreting its results, and the test's complications and limitations [Gorczyca et al., 1997; Orel, 2000].

Table 7 shows the mean sensitivities and specificities and the positive and negative predictive values of the three techniques for detecting breast implant rupture. These results agree with those of a recently published meta-analysis [Goodman et al., 1998]. The unweighted mean sensitivities of mammography, ultrasound and MRI were determined to be 28.4%, 59% and 78%, respectively. The mean specificities of the three techniques were 93%, 76.8% and 80%, respectively.

Table 7. Sensitivity, specificity and positive and negative predictive values of the three techniques for detecting breast implant rupture

Technique	Sensitivity mean % (range)	Specificity mean % (range)	PPV mean %	NPV mean %
Mammography	25 (5 to 81)	97 (82 to 100)	88	63
Ultrasonography	56 (25 to 100)	77 (55 to 96)	60	73
MRI	77 (46 to 100)	94 (55 to 100)	90	85

Samuels and collaborators proposed an algorithm for assessing implant integrity (Appendix E) [Samuels et al., 1995]. In the presence of clinical signs of implant rupture (sudden change in breast size or texture, asymmetry, nodules, other symptoms), mammography (Eklund technique) and ultrasound are performed. If the results of these two examinations are normal, a clinical follow-up is recommended. If they are abnormal, the implant is removed. If the results are equivocal or suspicious (possible rupture of the posterior wall, severe capsular contracture, internal structure of the implant suspicious, need to determine if there is any extracapsular silicone), an MRI is performed. If the MRI results are abnormal, the implant must be removed. If they are normal, the patient undergoes a clinical follow-up. These conclusions are confirmed by Orel, who considers MRI the most sensitive technique for detecting breast implant rupture, but that, because of its high cost, it should be reserved for implants where the evaluation by conventional techniques, such as mammography and ultrasound, does not yield conclusive results [Orel, 2000]. These proposals are consistent with the results presented in Table 7.

In the specific case of breast implants, it should be noted that not all plastic surgeons systematically recommend removal in cases of intracapsular rupture, for if the rupture is intracapsular, the silicone will not escape from the capsule. And some women may choose to keep their implants and undergo a regular clinical follow-up. This issue has still not been resolved. The FDA recommends removal in all cases of rupture, but recent publications bear witness to a debate among plastic surgeons about this in cases of asymptomatic rupture [FDA, 2000; Hölmich et al., 2001; Young and Watson].

5.2 Diagnosing breast cancer in the presence of breast implants

The Eklund technique, described in 1988, is a modified compression maneuver that permits better visualization of breast tissue in the presence of an implant. This is achieved by pushing the prosthesis back against the chest wall and pulling the breast tissues anteriorly. This technique should be performed when standard views are taken in the craniocaudal and mediolateral oblique projections. Thus, four views are taken for each implanted breast: two after the Eklund maneuver and two without the maneuver. Even if this modified compression technique is used, visualization of the breast tissues is limited because of the implant. Indeed, the radio-opacity of silicone and compression of the breast tissues by the implant can hinder the early detection of breast cancer [IOM, 2000].

The IOM committee analyzed the results of 12 studies concerning breast cancer detection in 320 women with breast prostheses, 278 of whom had mammography revealing 264 breast tumors. Most of the participants enrolled between 1978 and 1992 did not undergo the Eklund technique, which was which was developed in 1988. Mammography alone was performed in 14% of the women, a clinical examination only in 48% of them, and both modalities in the remaining 37%. Since the study reports do not specify which proportion of the mammographies were for screening, the early cancer detection rate in the presence of implants cannot be determined. The committee points out that, according to the results of some of these studies, the primary tumors were larger in women with implants than in women without implants at the time of diagnosis, the incidence of confirmed positive axillary nodes was higher, or the proportion of palpable tumors visible on mammography was lower, although no such differences were observed in the participants in other studies. Furthermore, calcification in the periprosthetic capsule, whether the implant is still in place or after explantation, could lead to a false-positive diagnosis of cancer and unnecessary additional diagnostic tests or therapeutic interventions. On the other hand, a false negative can be obtained if calcifications are attributed to the presence of the periprosthetic capsule when they are actually a sign of cancer. The IOM committee believes that the presence of implants prevents complete visualization of breast tissue but that, based on the data, it cannot be said to what extent implants hinder breast cancer detection [IOM, 2000].

6. Silicone toxicity

Silicone gel breast implants have been associated with significant local complications and with the possibility of systemic morbidity. The IOM committee conducted an exhaustive study of the toxicity of silicone and of the systemic complications associated with breast implants. This chapter presents the committee's main conclusions and summarizes the latest publications on the subject.

The committee examined published scientific data on immune response or the absence thereof in the presence of silicone in its various forms in animals and humans. In these studies, a distinction was seldom made between the type of implant and its contents, i.e. saline or silicone gel. In the committee's opinion, there is no evidence that silicone or silicone gel implants have any clinical effects on the immune system. However, this conclusion might be due to a lack of rigorous studies. Some forms of silicone can apparently act as an adjuvant, but there is no evidence that this has any clinical significance. The results of well-designed scientific studies suggest that there is no link between breast implants and the formation of antinuclear antibodies [IOM, 2000].

The connective tissue diseases, or collagen diseases, include particularly systemic lupus erythematosus, rheumatoid arthritis, Sjögren's syndrome, systemic sclerosis or scleroderma, dermatomyositis/polymyositis and others. The IOM committee analyzed data from 17 epidemiological study reports on connective tissue diseases in women with breast implants (11 cohort studies, 5 case

control studies and 1 cross-sectional study). In most cases, all of the collagen diseases were taken into consideration, although in 7 studies, only one specific disease was looked at. In most of the studies, a distinction was not made in terms of the implant's contents (saline or silicone gel). The results of just one of these 17 studies show a significant increase in the risk of collagen disease (RR = 1.24; 95% CI: 1.08 to 1.41) [Hennekens et al., 1996]. The IOM committee concludes that there are no scientific data to support the existence of a link between breast implants and connective tissue diseases. In fact, the authors of a good number of these studies have mainly concluded that there is no such link [IOM, 2000].

The results of four meta-analyses have been published on a possible link between breast implants and collagen diseases and autoimmune diseases. The most recent meta-analysis, published by Janowsky and collaborators, included the results of 20 studies (9 cohort studies, 9 case control studies and 2 cross-sectional studies). If one excludes Hennekens and colleagues' study, it cannot be concluded from the results that breast implants increase lead to an increased risk of developing the following diseases considered individually—rheumatoid arthritis (RR = 1.04; 95% CI: 0.72 to 1.51), systemic lupus erythematosus (RR = 0.65; 95% CI: 0.35 to 1.23), systemic sclerosis or scleroderma (RR = 1.01; 95% CI: 0.59 to 1.73), Sjögren's syndrome (RR = 1.42; 95% CI: 0.65 to 3.11) and other rheumatic or autoimmune diseases (RR = 0.96; 95% CI: 0.74 to 1.25)—or all these diseases considered together (RR = 0.80; 95% CI: 0.62 to 1.04). If, on the other hand, the results of Hennekens's study are included, we observe a significant increase in the risk of all collagen diseases combined (RR = 1.14; 95% CI: 1.01 to 1.28) and of Sjögren's syndrome in particular (RR = 1.47; 95% CI: 1.01 to 2.14) [Janowsky et al., 2000]. Hennekens and collaborators reported a significant increase in the risk of collagen diseases in a cross-sectional study involving some 400,000 women [Hennekens et al., 1996]. The diagnosis-related data were obtained by survey, while the rupture-related data came from the medical records in all of the other studies. The risk of dermatomyositis/polymyositis was calculated only by Hennekens and colleagues and is not significant (RR = 1.52; 95% CI: 0.97 to 2.37).

Based on the relative risks determined in their meta-analysis, Janowsky and collaborators [2000] calculated the risk attributable to the use of breast implants in the population. According to their evaluation, 4.3 of the 3,303 new cases of rheumatoid arthritis diagnosed each year, 0.1 of the 526 new cases of systemic lupus erythematosus, 0.4 of the 164 new cases of scleroderma, 1.3 of the 400 new cases of Sjögren's syndrome and 0.2 of the 54 new cases of dermatomyositis can be attributed to breast implants in a reference population of 10 million women in the United States [Janowsky et al., 2000].

Lieberman and Zuckerman reviewed the results of the 20 studies included in Janowsky's meta-analysis and point out their methodological flaws [Lieberman and Zuckerman, 2000]. For example, the basic data used in several studies came from the participants' medical or hospital records, yet most of the health problems associated with implants do not require hospitalization. Furthermore, the samples were small, and several studies included women who may have had an implant for a short time, less

than a year in some cases. In addition, the meta-analysis concerned studies whose results had not been published and whose methodology was not explained clearly enough to assess the validity of the results. These methodological flaws should therefore be borne in mind when interpreting the results of Janowsky and colleagues' meta-analysis.

Other studies have looked at the relationship between breast implants and an atypical connective tissue disease. The disease has various manifestations, such as chronic fatigue, joint pain, myalgia, muscle weakness and memory difficulties. The IOM committee concludes that there is insufficient evidence to support a link between breast implants and the development of this new syndrome [IOM, 2000]. A systematic data review by Tugwell and colleagues did not reveal a causal link between implants and connective tissue diseases [Tugwell et al., 2001]. The results obtained are not conclusive for some of the symptoms considered individually, such as arthralgia, myalgia and adenopathies.

The IOM committee examined the scientific data concerning the putative link between silicone exposure and the use of silicone gel implants on the one hand, and carcinogenesis and breast cancer on the other. They concluded that the current scientific data do not support the existence of such a link between silicone or silicone gel breast implants and experimental carcinogenesis, primary or recurrent breast cancer, breast sarcoma or other solid breast tumors, lymphoma or myeloma [IOM, 2000]. A large, ongoing study in Canada is aimed at determining if the use of breast prostheses leads to an increased risk of cancer and other health problems. The study is comparing 40,000 implanted women with 20,000 women who have undergone other types of cosmetic surgery. The results have not yet been published.

The presence of silicone in breast tissues due to implant rupture or gel migration causes local neurological complications as a result of nerve compression. Apart from this particular effect, the presence of silicone in breast tissues does not increase the risk of neurological problems, according to the conclusions of two epidemiological studies involving large cohorts of implanted women (approximately 4,600) [IOM, 2000].

The IOM committee examined the possibility that women with silicone gel breast prostheses can transfer silicone or immune factors to their child during pregnancy or breast-feeding. There is not enough scientific data to confirm this hypothesis. The data indicate that the silica concentration of breast milk is the same in women with and without implants [IOM, 2000].

As for local complications, the IOM committee considers that several of them, in particular, rupture, deflation, periprosthetic contracture, infection and postoperative hematomas, require surgical intervention. These local complications are frequent and are presently one of the more important health problems associated with breast implants [IOM, 2000].

7. POSITIONS OF VARIOUS INSTITUTIONS REGARDING THE DETECTION OF SILICONE GEL BREAST IMPLANT RUPTURE

Various organizations and authors have made recommendations concerning a) the measures recommended after detecting silicone gel breast implant rupture; b) the need for a systematic and periodic implant rupture screening program; and c) the need for a national registry of women with breast implants.

In Canada, an independent advisory committee on silicone gel breast implants came out against periodic implant rupture screening by mammography in women under the age of 35. The only exception to this would be cases where the benefits of screening unquestionably outweigh the cumulative risk of radiation exposure [Independent Advisory Committee on Silicone-Gel-Filled Breast Implants, 1992].

This position is similar to that of an FDA committee. In light of the information available in 1992, the committee came out against systematic implant rupture screening in asymptomatic women, pointing out that removal does not confer any health benefits. Systematic screening would detect subclinical ruptures that will not develop into clinical problems and would lead to explantation, which involves risks and which can have adverse aesthetic consequences. The committee nonetheless recommended explantation as soon as a rupture is detected [Brown et al., 1997].

The French agency ANDEM reached the same conclusion in 1996. It concluded that, given the sensitivity and specificity of the imaging techniques and the feasibility problems, instituting a systematic imaging-based screening program could not be recommended. Rather, a clinical follow-up should be provided, with use made of mammography on a first-recourse basis in order to guide the explantation decision as soon as a rupture is suspected [ANDEM, 1996].

The Netherlands Health Council recently recommended the setting up of a national registry and the close monitoring of all women with silicone gel breast implants in order to detect any ruptures as soon as possible. However, the council's report does not give any recommendations with regard to the follow-up method or modalities [Gezondheidsraad, 1999].

In its recently published report, the IOM finds that there is insufficient evidence to support systematic implant rupture screening in asymptomatic women. For the purpose of assessing implant integrity, the IOM committee recommends the use of mammography and ultrasound if signs of loss of implant integrity (sudden change in size, pain, asymmetry) are observed on clinical examination. If the results from both imaging modalities are normal, a clinical follow-up should be done. If both modalities unequivocally show a rupture, removal should the considered. MRI is recommended in all cases where the mammography and ultrasound results are inconclusive [IOM, 2000].

8. CURRENT STATUS OF SILICONE GEL BREAST IMPLANTS IN QUÉBEC

8.1 Legal and regulatory context

In April 1991, polyurethane-coated silicone gel breast implants (for example, Même) were voluntarily withdrawn from the market by the manufacturers. Subsequently, concern over the potential health risks due to the leakage of silicone gel led to a moratorium on the use of all silicone implants in Canada and the United States. The moratorium, which was adopted in January 1992, is still in effect [Health Canada, 1998]. At the time, several types of breast implants were commercially available in Canada, but the most popular ones were silicone gel-filled, since their texture gives them a more natural appearance. The other types of implants available were single-lumen saline-filled and double-lumen implants, with the inner compartment filled with silicone and the outer compartment with saline or vice versa [Health Canada, 2000].

Manufacturers of silicone gel breast implants that wish to obtain authorization from Health Canada must demonstrate the safety, quality and efficacy of their product [Health Canada, 2000]. Because of concerns over breast implants and their effects on women's health, Health Canada has set up an intensive research program for the purpose of examining the potential health risks associated with breast implants[3]. One of the studies specifically deals with the morbidity, mortality and cancer survival rate in women who have received breast implants for cosmetic reasons in Québec and Ontario. The results of the study have not yet been published.

Several lawsuits have been instituted in Québec against different breast implant manufacturers. Until now, the class action lawsuits have ended in out-of-court settlements, with the result that there have not been any proceedings (information provided by the organization Option Consommateurs and Alexandra Obadia, jurist, in November 2000).

8.2 Extent of the practice

By extrapolating from U.S. data, we estimate that between 100,000 and 200,000 Canadian women have received breast implants since the early 1960s [Independent Advisory Committee on Silicone Gel-Filled Breast Implants, 1992]. This is more or less a rough estimate, mainly because the number of women and the number of implants do not match. According to Health Canada, since 1984, more than 12,000 polyurethane foam-coated breast implants have been sold in Canada, 10,000 of which in Québec [Health Canada, 1998].

Although these figures are not very accurate, they are the only ones that we have regarding the number of Canadians and Quebecers with breast implants. The reasons for this are that there is no national registry, that cosmetic augmentation surgery is not necessarily performed at hospitals and

[3] http://www.hc-sc.gc.ca/main/lcdc/web/bc/implant/notice_f.html, consulted on January 19, 2001.

that the cost of these interventions is not covered by Québec's public health insurance plan. Because of the latter two reasons, the information found in the databases that are usually consulted, such as the hospital discharge database (Med-Écho) and the medical procedure database of the Régie de l'assurance-maladie du Québec (RAMQ), is incomplete.

In the United States, between 20 and 30% of implants are for breast reconstruction following mastectomy, either after cancer treatment or as a preventive measure (family history or risk of mastopathy). The other 70 to 80% are performed for augmentation of one or both breasts for cosmetic purposes [Brown et al., 1997; IOM, 2000]. There are no comparable data on the use of breast implants in Canada or Québec.

8.3 Description of the practice

In Québec, plastic surgery for breast reconstruction is performed at short-term care hospitals and at private plastic surgery clinics. The costs associated with implantation following mastectomy, with treating breast hypoplasia or asymmetry, or with the complications that can result from these procedures (hematoma, infection, surgical removal of prosthesis, etc.) are usually covered by the RAMQ. The RAMQ does not cover the cost of cosmetic augmentation surgery, but it does assume the cost of care in the event of complications following cosmetic mammoplasty when the physician considers such care medically necessary[4].

Systematic, periodic implant rupture screening is not performed in asymptomatic women. However, a radiologist may, while performing an examination in the province's breast cancer screening program, check the integrity of an implant and detect any change in its configuration or the presence of free silicone in the mammary parenchyma (extracapsular rupture).

Mammography and ultrasound are examination techniques available everywhere in Québec, and mammography is already performed in a good number of women for breast cancer screening purposes. Accessibility to MRI is quite limited in Québec. According to a recently published survey, there were, as at July 15, 2001, 23 MRI scanners in Québec, 14 of which were in the Montréal area [CCOHTA, 2001]. The waiting list for MRI is a few months to more than a year.

9. DISCUSSION

Rupture is one of the local complications of breast implants. Its prevalence is not known with certainty, but it is estimated that the implants currently available have a lifespan of some 10 years. In an

[4] Written communication from J.P. Lévesque, Division of Eligibility and Information for Insured Persons, Régie de l'assurance-maladie du Québec, January 31, 2000.

intracapsular rupture (80% of cases), the silicone remains within the fibrous capsule surrounding the implant. Although it is more frequent, this type of rupture is generally asymptomatic and does not result in a loss of esthetics. Since an intracapsular rupture can become extracapsular, its detection should be an indication for removal. However, in practice, there is no general agreement over this. Removal requires the surgical extirpation of the implant and of the fibrous capsule surrounding it and results in a significant loss of esthetics. It should be borne in mind that breast augmentation by implant placement is performed in women who have undergone mastectomy because of breast cancer, in cases of breast hypoplasia or asymmetry, or for purely cosmetic reasons. In all these cases, the ultimate objective is to improve the woman's body image. Surgical removal, including extirpation of the implant and capsule, can lead to deformity and have untoward esthetic consequences.

Extracapsular rupture occurs less frequently but allows the silicone to escape outside the capsule and results in breast deformity. Once such a rupture is detected, it is dealt with by surgical removal.

Based on the current scientific data regarding the toxicity of silicone and on the conclusions of the IOM committee, which examined this matter in depth, a verdict cannot be reached as to the consequences of the use or rupture of silicone gel-filled breast implants on women's health. Controversy therefore persists, and this matter continues to be investigated.

A clinical examination performed by an experienced physician is the primary follow-up modality for a woman with breast implants. In some cases, a clinical examination may suffice to determine the timeliness of removing a defective implant. Several breast imaging techniques are capable of detecting implant rupture. We examined the validity of the following three techniques: mammography, ultrasonography and MRI. As a general rule:

- A very sensitive test will yield a low false-negative rate. In other words, the probability of not detecting cases of rupture is lower. The test's sensitivity is important, given the potentially toxic effects of silicone.
- A very specific test will yield a low false-positive rate. In other words, the probability that its result will lead to the unnecessary removal of an intact implant is lower. Implant removal includes extirpation of the fibrous capsule and can have untoward esthetic consequences, and yet, esthetic considerations are the very reason for breast augmentation surgery.
- The predictive value is the probability that an implant is actually ruptured when the test result is positive or that it is intact when the test result is negative. These probabilities weigh heavily when deciding to remove or not to remove an implant after a positive or negative result is obtained.

Most studies have examined the efficacy of just one diagnostic technique. A few studies involved a parallel comparison of the three techniques performed in the same groups of patients and thus made it possible to evaluate the diagnostic validity of mammography, ultrasonography and MRI. Based on the results of comparative studies, mammography is more specific than sensitive in detecting prosthetic

rupture. It has a low sensitivity (between 5 and 81%) but a high specificity (between 82 and 100%).

Ultrasound is capable of detecting intracapsular and extracapsular ruptures. Its diagnostic validity is comparable to that of mammography, although its specificity is slightly lower (sensitivity of 25 to 100%; specificity of 50 to 92%). MRI is the most sensitive technique (sensitivity of 46 to 100%) for detecting prosthetic rupture, and it is capable of detecting both intracapsular and extracapsular ruptures. Its specificity is comparable to that of mammography or slightly lower (specificity of 55 to 100%).

The three imaging techniques have a high specificity, but MRI is the most sensitive one. However, in the specific case of breast implant rupture, a high sensitivity offers the possibility of detecting intracapsular ruptures and bleed, which might be clinically silent but which, once detected, will lead to explantation. The scientific data do not enable us to document the impact of the type of rupture on the results obtained with the various techniques, but it is recognized that mammography is very sensitive in detecting extracapsular ruptures, which constitute an absolute indication for surgical removal, although such ruptures are less frequent.

Sequential-type protocols have been proposed in which mammography and ultrasound are performed first, followed by MRI in those cases where the first two examinations yield suspicious or inconclusive results. These protocols are based on the fact that MRI is a very sensitive and specific test, although it is expensive and not very accessible. It should be used only if doubt persists, despite the conventional examinations. This is the position of most official organizations that have expressed an opinion about this.

10. CONCLUSIONS AND RECOMMENDATION

In light of the scientific data examined in this report, AETMIS draws the following conclusions:

Conclusions

- The current state of knowledge reveals a lack of scientific data demonstrating the toxicity of silicone or its adverse health effects in women. This said, breast implant rupture would have esthetic consequences and cause local complications. However, if silicone turns out to be toxic to women, research should focus on the very use of breast implants rather than on implant rupture, for it is recognized that silicone migrates, even from intact implants, and that an implant shell is a source of silicone exposure.

- For now, published study reports do not provide explicit justification for setting up a program for implant rupture screening in asymptomatic women, since most of these studies involved women in whom the likelihood of rupture was high.

- Few studies have examined the role of mammography in iatrogenic implant rupture. If there is a breast implant, certain maneuvers should be performed before views are taken. The compression required during mammography could exacerbate a preexisting defect or cause an intracapsular rupture to become extracapsular, without constituting the primary cause of the rupture.

- The utility of MRI seems to reside in better detection of intracapsular rupture. However, such ruptures are generally asymptomatic, and there is no consensus regarding the indication for removal.

- Since MRI is slightly less specific than mammography in detecting extracapsular rupture, its use could result in the removal of intact implants. Yet, the risks and adverse esthetic consequences of this procedure could be worse than those associated with keeping the implant in place, despite an intracapsular rupture.

- MRI is an expensive technique, and in Québec, time on the waiting list for MRI is at least one year. Mammography and ultrasonography are accessible screening tools and are already being used by the vast majority of the women in the Québec Breast Cancer Screening Program or, outside this program, for diagnostic purposes.

Recommendation

- Given the data on the efficacy and accessibility of the different techniques, AETMIS believes that, if there is a clinical presumption of rupture, the course of action should be modeled on that one which is detailed in the algorithm proposed by Samuels and colleagues [Samuels et al., 1995] and which is embraced by the IOM [IOM, 2000]. A mammographic examination followed by a breast ultrasound is the recommended strategy of first recourse. If the results of these two examinations are normal, it is advisable to provide a clinical follow-up. If either of these examinations reveals an extracapsular rupture, the implant is removed. If the results of these examinations reveal an intracapsular rupture, some women may choose to keep their implants and to undergo a periodic clinical follow-up. Lastly, if the results are equivocal or suspicious or do not agree with the findings of the clinical examination, MRI is performed.

APPENDIX A

Table A.1. Studies involving a parallel comparison of two or three detection techniques, with confirmation of rupture at explantation

Study	Number of implants	Number and type(s) of ruptures	Methodology	Technique	Comments
Everson et al., 1994 U.S.	**63**	**22** (21 ICs and 1 EC)	Prospective study. Women (except one) with signs and symptoms of rupture.	**Mammography**: 4 views (Eklund). **Ultrasonography**: 5–10-MHz transducer. **MRI**: 1.5 T, dedicated surface coil.	Good description of the rupture detection criteria for each technique. Whether rupture included extravasation or bleed is not stated.
Monticciolo et al., 1994 U.S.	**38**	**18**	Prospective study. Women with signs or symptoms of rupture.	**Mammography**: Not described. **MRI**: 1.5 T, standard circular surface coil.	Mention of silicone gel extravasation with no distinction between extracapsular and intracapsular rupture. Three false negatives with mammography in subjects with intracapsular rupture.
Reynolds et al., 1994 U.S.	**24**	**13**	Prospective study. Women with symptoms or who wanted their implants removed.	**Mammography**: 4 views (Eklund) in 11 of the 13 women. **Ultrasonography**: 7.5-MHz transducer. **MRI**: 1.5 T. Dedicated surface coil used in 5 women (10 implants).	Definition of rupture including all cases in which there was silicone gel outside the implant, whether minimal extravasation or extracapsular rupture. Images classified into three categories (normal, suspicious and diagnostic). Their predictive value can differ according to the technique.
Berg et al., 1995 U.S.	**144**	**80**	Prospective study. Removal because of diagnosis of rupture or because of pain or capsular contracture.	**Ultrasonography**: 5- or 7.5-MHz transducer. **MRI**: 1.5 T, with and without dedicated surface coils.	Separate examination of each sign observed on ultrasonography and MRI, followed by an overall assessment of implant integrity. Separate evaluation of single- and double-lumen implants, and of cases of rupture and bleed.

CC: capsular contracture; EC: extracapsular rupture; IC: intracapsular rupture

Table A.1 (Cont'd). Studies involving a parallel comparison of two or three detection techniques, with confirmation of rupture at explantation

Study	Number of implants	Number and type(s) of ruptures	Methodology	Technique	Comments
Robinson et al., 1995 U.S.	**133**	**83**	Prospective study. Symptomatic cases.	**Mammography** **MRI**	No rupture or bleed classification. No description of techniques. Only 10 implants examined by MRI.
Weizer et al., 1995 Netscher et al., 1996 U.S.	**160**	**42**	Prospective study. Symptomatic cases.	**Mammography**: 4 views (Eklund). **Ultrasonography**: 5–7.5-MHz. **MRI**: 1.5 T, without dedicated surface coil at first, then with a surface coil.	Two EC ruptures and no IC ruptures detected with mammography. MRI had higher sensitivity and specificity thanks to the new, dedicated surface coils.
Ikeda et al., 1999 U.S.	**31**	**18** (5 extrava-sations, 4 ECs and 9 ICs)	Prospective study. Strong likelihood of rupture.	**Mammography**: 4 views (Eklund). **Ultrasonography**: 7.5-MHz transducer. **MRI**: 1.5 T, dedicated surface coil.	Implant classified as follows: intact, intact with extravasation, intracapsular rupture and extracapsular rupture.
Beeckman et al., 1999 The Netherlands	**35**	**16** (16 ICs)	Prospective study. Strong likelihood of rupture.	**Ultrasonography**: 7.5–10-MHz transducer. **MRI**: 4.5 Tesla, Siemens Magnetom SP 63; dedicated surface coils.	Extravasation of silicone gel diagnosed in 5 women, but no cases detected prior to surgery. Single-lumen silicone gel implants only.

CC: capsular contracture; EC: extracapsular rupture; IC: intracapsular rupture

APPENDIX B

Table B.1. Evaluative studies of a detection technique, with confirmation of rupture at explantation

Study	Number of implants	Number and type(s) of ruptures	Diagnostic technique	Method	Comments
Gorczyca et al., 1992 U.S.	140	21 (19 ICs et 2 ECs)	MRI	Retrospective evaluation of the MRI images by two radiologists. Women referred because of local or regional pain and systemic symptoms. MRI: 1.5 T, with standard surface coil.	Mammography performed in 16 of the 21 cases of rupture. Both ECs detected, but none of the 14 ICs.
DeBruhl et al., 1993 U.S.	57	20 (16 ICs and 4 ECs)	Ultrasonography	Prospective evaluation of 74 symptomatic women, 28 of whom underwent explanation (57 implants). Ultrasonography: 3 scanners with a 10-MHz mechanical transducer; 5–10-MHz linear transducer; and a 10-MHz linear array transducer.	10 of the 16 intracapsular ruptures and of 2 of the 4 extracapsular ruptures were correctly identified. Problems observed: Evaluation of posterior wall of the implant difficult, lack of operator experience, and learning curve, plus difficulty determining if the woman had had silicone injections.
Caskey et al., 1994 U.S.	59	22 (21 ICs and 1 EC)	Ultrasonography	Prospective clinical and sonographic evaluation of 119 women. Surgical confirmation obtained in 31 symptomatic cases. Ultrasonography: 5- or 7.5-MHz linear array transducers.	Evaluation by ultrasonic signs. Most frequent signs: low-level homogeneous echoes, which have a sensitivity of 55% and a specificity of 84%.

CC: capsular contracture; EC: extracapsular rupture; IC: intracapsular rupture

Table B.1 (Cont'd). Evaluative studies of a detection technique, with confirmation of rupture at explantation

Study	Number of implants	Number and type(s) of ruptures	Diagnostic technique	Method	Comments
Chilcote et al., 1994 U.S.	42	20 (20 ICs, including 7 ruptures and 13 extra-vasations)	Ultrasonography	Prospective evaluation of 25 women (42 implants) with signs or symptoms of implant rupture. No rupture was evident on physical examination. Ultrasonography: 5.58-MHz linear transducer.	Examination of all ultrasound images by four radiologists. Results classified into 5 categories: 1) intact; 2) probably intact; 3) uncertain; 4) probably ruptured; 5) ruptured. When calculating the sensitivity, 4 and 5 were considered intact, and when calculating the specificity, 1, 2 and 3 were considered ruptured.
Dobke and Middleton, 1994 U.S.	74	24 (16 ruptures and 8 cases of bleed)	MRI	Retrospective evaluation of 39 women (74 implants). MRI: 1.5 T, dedicated bilateral surface coil.	Just one inaccurate result for 74 implants examined by MRI.
Gorczyca et al., 1994 U.S.	81	18 (16 ICs and 2 ECs)	MRI	Retrospective evaluation of 82 symptomatic women. 41 underwent surgery to remove implants (81). MRI: 1.5 T, standard and dedicated surface coils.	Four radiologists reviewed the images obtained. The interobserver differences were not significant. The study compared two MRI techniques in the detection of breast implant rupture.
Liston et al., 1994 United Kingdom	43	13	Ultrasonography	Prospective preoperative evaluation of 24 women (43 implants). Ultrasonography: 5-MHz curvilinear transducer.	Classification of implants: intact (30), with localized loss of shell integrity (6) or completely disintegrated (7). All the ultrasounds were performed by the same radiologist.
Petro et al., 1994 U.S.	22	7	Ultrasonography	Prospective evaluation. Ultrasonography: high-resolution transducers (5.0-, 7.5- and 10-MHz)	All the ultrasounds were performed by the same radiologist. The surgical findings matched for only 22 of the 94 implants examined. Specificity calculated on the basis of all the implants (62/87).

CC: capsular contracture; EC: extracapsular rupture; IC: intracapsular rupture

Table B.1 (Cont'd). Evaluative studies of a detection technique, with confirmation of rupture at explantation

Study	Number of implants	Number and type(s) of ruptures	Diagnostic technique	Method	Comments
Chung et al., 1996 U.S.	**192**	**62**	Ultrasonography	Prospective evaluation of ultrasound for the detection of silicone breast implant rupture in 98 asymptomatic women (192 implants). Ultrasonography: 7.5-MHz transducer.	If cases of silicone gel leakage are considered ruptures, the sensitivity increases from 74 to 89%, the specificity from 89 to 96%. The positive and negative predictive values increase as well.
Quinn et al., 1996 U.S.	**108**	**30** (29 ICs and 1 EC)	MRI	Prospective and retrospective evaluation. MRI: 1.5 T, dedicated surface coils.	Prospective interpretation, by a radiologist, of an MRI performed prior to surgery (Sn: 87%; Sp: 78%). Retrospective interpretation, by two radiologists, of MRI images of women who had undergone explantation, with the radiologists blinded to the status of the implants at surgery (Sn: 93%; Sp: 92%). Difficulty interpreting the difference between an IC and a large leak with an intact capsule.
Venta et al., 1996 U.S.	**78**	**22**	Ultrasonography	Prospective evaluation of 126 women with breast implants with or without symptoms. Explantation performed in 43 women (78 implants). Ultrasonography: 5–7-MHz transducer.	Evaluation of the influence of the learning curve on sensitivity and specificity by means of ROC curves. Finding: The learning curve influences image interpretation. Results not significant. No significant interobserver variation.

CC: capsular contracture; EC: extracapsular rupture; IC: intracapsular rupture

Table B.1 (Cont'd). Evaluative studies of a detection technique, with confirmation of rupture at explantation

Study	Number of implants	Number and type(s) of ruptures	Diagnostic technique	Method	Comments
Medot et al., 1997 U.S.	**122**	**49** (17 with CC, 32 without CC)	Ultrasonography	Retrospective chart review of 65 women (122 silicone breast implants) who had undergone explantation. Ultrasonography: 10-MHz, high-frequency transducer.	Reasons for consultation: symptoms or concerns about implants. Each women had undergone a physical examination and ultrasonography. Removal in all cases of confirmed rupture and in women who wanted explantation, even if the implant was intact on ultrasonography.
Middleton, 1998 U.S.	**785**	**394** (306 ICs, 87 ECs, 1 not specified)	MRI	Retrospective review of 1,305 women examined by MRI since 1992 at the UCSD. MRI of 1,626 single-lumen implants and removal in 785 cases. MRI: 1.5 T, dedicated surface coils.	Single-lumen implants only. The study took place over a long period of time. No mention is made if any results had already been presented in other reports. Thorough review of the implants, complications, and images showing rupture and the presence of free silicone in soft tissues.

CC: capsular contracture; EC: extracapsular rupture; IC: intracapsular rupture

APPENDIX C

Table C1. Studies not included in the analysis

Study	Number of implants	Number and type(s) of ruptures	Methodology	Detection technique	Reasons for exclusion
Andersen et al., 1989 U.S.	**?**	**?**	Retrospective review of 18 women treated by the authors and 14 women included in previous studies.	**Mammography**	Number of implants examined not specified. Not enough data to calculate the test's validity. Mammography technique not described.
Ahn et al., 1994 U.S.	**59**	**21** (18 ICs and 3 ECs)	Prospective study. Symptomatic cases.	**Mammography**: 4 views (Eklund). **Ultrasonography**: 3 instruments: 10-MHz mechanical transducer; 5–10-MHz linear transducer; 10-MHz linear transducer. **MRI**: 1.5 T (intensity of magnetic field), dedicated surface coils.	Insufficient data (in actual numbers) to construct a 2-row, 2-column table (2 x 2).
Beekman et al., 1996 The Netherlands	**76**	**39**	Study design? Symptomatic cases.	**Mammography:** No details. **Ultrasonography**: 7.5-MHz transducer.	Combined use of mammography and ultrasonography. Protocol for using the two techniques not provided. The results are grouped together.

Table C1 (Cont'd). Studies not included in the analysis

Study	Number of implants	Number and type(s) of ruptures	Methodology	Detection technique	Reasons for exclusion
Soo et al., 1997 U.S.	**86**	**48** (48 ICs)	Retrospective study. Symptomatic cases.	**MRI**: 1.5 T, dedicated breast coils	Comparison of the validity of the various signs and combinations as rupture detection criteria.
Rohrich et al., 1998 U.S.	**292**	**114** ruptures **76** cases of bleed	Retrospective study. 357 implants extirpated over a 5-year period.	**Mammography** **MRI** Details of the techniques used not provided.	Insufficient data (in actual numbers) to construct a 2-row, 2-column table (2 x 2).

APPENDIX D

Table D.1. Summary of the results of the studies included in this report

Study	Number of women (implants)	Mammo-graphy	Ultra-sound	MRI	Mammo-graphy	Ultra-sound	MRI
		Sensitivity			Specificity		
DeBruhl et al., 1993	28 (57)	-	70	-	-	92	-
Caskey et al., 1994	31 (59)	-	55	-	-	84	-
Chilcote et al., 1994	25 (42)	-		-	-		-
Rupture only			50			75	
Rupture and bleed			25			75	
Liston et al., 1994	24 (43)	-	69	-	-	96	-
Petro et al., 1994	(22)	-	100	-	-	-	-
Chung et al., 1996	98 (192)	-	74	-	-	89	-
Venta et al., 1996	43 (78)	-	50	-	-	55	-
Medot et al., 1997	65 (122)	-	59	-	-	73	-
With CC	85		41			70	
Without CC	37		69			74	
Gorczyca et al., 1992	70 (140)	-	-	76	-	-	97
Dobke and Middleton, 1994	39 (74)	-	-	100	-	-	98
Gorzcyca et al., 1994	41 (81)	-	-		-	-	
3-point Dixon				61			97
FSE				89			97
Quinn et al., 1996	54 (108)						
Prospective		-	-	87	-	-	78
Retrospective		-	-	93	-	-	92
Middleton, 1998	(785)	-	-	74	-	-	98
Everson et al., 1994	32 (63)	23	59	95	98	79	93
Monticciolo et al., 1994	28 (38)	81	-	94	100	-	100
Reynolds et al., 1994	13 (24)	69	54	69	82	64	55
Berg et al., 1995	(144)	-			-		
Single-lumen			49	78		57	91
Double-lumen			8	75		20	90
Robinson et al., 1995	(133)*	17		72	92		67
Weizer et al., 1995 Netscher et al., 1996	81 (160)	5	47	46	100	83	88
Ikeda et al., 1999	16 (31)	33	67	100	100	62	77
Beekman et al., 1999	18 (35)	-	44	88	-	84	100

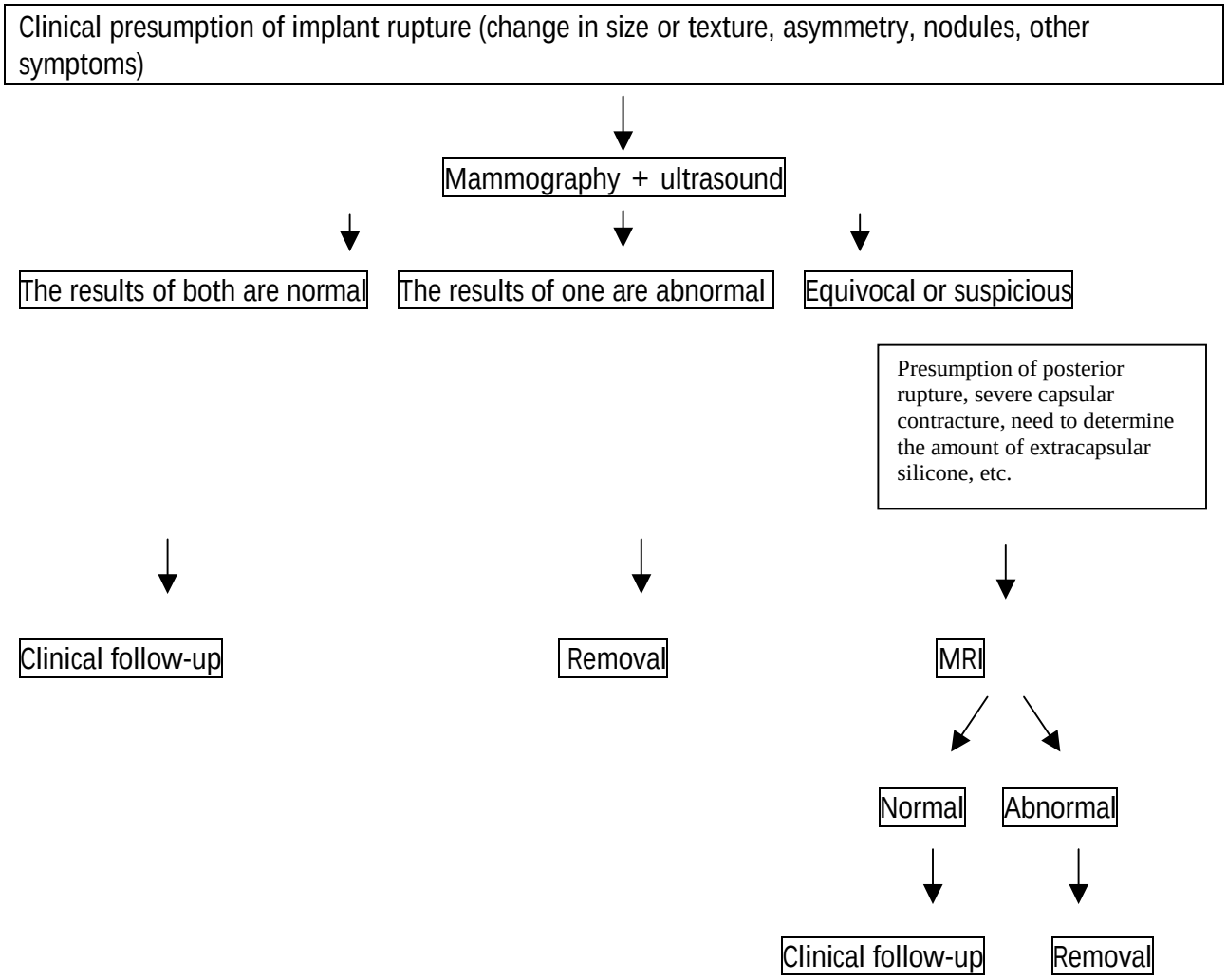
CC: capsular contracture

FSE: fast spin echo

*Only 10 implants were examined by MRI.

APPENDIX E

Algorithm proposed by Samuels and colleagues for detecting silicone breast implant rupture [Samuels et al., 1995].



LIST OF ABBREVIATIONS

A:	Accuracy
ANDEM:	Agence Nationale pour le Développement de l'Évaluation Médicale, a French agency renamed *Agence Nationale d'Accréditation et d'Évaluation en Santé* (ANAES)
CC:	Capsular contracture
CI:	Confidence interval
FDA:	Food and Drug Administration (U.S.)
FSE:	Fast spin echo
IOM:	Institute of Medicine (U.S.)
IRG:	Independent Review Group (United Kingdom)
MDA:	Medical Devices Agency (United Kingdom)
MRI:	Magnetic resonance imaging
NPV:	Negative predictive value
PPV:	Positive predictive value
QBCSP:	Quebec Breast Cancer Screening Program
RAMQ:	Régie de l'assurance-maladie du Québec (Québec, Canada)
RR:	Relative risk
Sn:	Sensitivity
Sp:	Specificity
TN:	True negative
TP:	True positive

GLOSSARY

Accuracy: Sum of the true positives (TP) and true negatives (TN) divided by the total number of implants examined. Formula: (TP + TN)/(TP + FP +TN + FN).

Adjuvant: A preparation which, when administered at the same time as an antigen, increases the immune response to the antigen.

Axillary adenopathy: Acute or chronic inflammation of the lymph nodes in the axillary fossa.

Breast coil: A surface coil used in magnetic resonance imaging of the breast. There are double breast coils for imaging both breasts simultaneously.

Capsular contracture: Prolonged contraction of the capsule surrounding an implant.

Capsule: The fibrous membrane consisting of dense connective tissue surrounding an implant. It can be supple or hard and tough. It can present with visible calcifications on mammography or computed tomography [Gorczyca et al., 1997; IOM, 2000].

Capsulotomy: Loosening of the periprosthetic capsule through external maneuvers (closed capsulotomy) or surgical intervention (open capsulotomy).

Case series: Descriptive study without a reference group.

Cohort study: A study conducted without a comparison group and in which the subjects are selected on the basis of one or more characteristics and followed over time to measure the effects of those characteristics.

Elastomer: A synthetic polymer with the properties of natural rubber, such as high extensibility and elastic recovery capability.

Excision: Surgical removal of an organ, tumor or foreign object.

Extracapsular rupture: A tear in the shell and the fibrous capsule surrounding an implant, with extravasation of the silicone gel into the surrounding tissues [Gorczyca et al., 1997].

Extravasation: The effusion of a fluid outside of the vessels or organs that normally contain it.

False-negative rate: The proportion of negative results (FN) yielded by a test in individuals with the disease. Formula: 1- sensitivity.

False-positive rate: The proportion positive results (FP) yielded by a test in individuals without the disease. Formula: 1- specificity.

Gel bleed: Microscopic diffusion of fluid silicone (oil or gel) through the intact shell of a silicone gel-filled implant. Gel bleed does not constitute rupture.
Iatrogenic rupture: Rupture of a prosthesis caused by a physician or by medical treatment.

Intracapsular rupture: A tear in an implant shell without extravasation of the silicone gel into the surrounding tissues, since the gel remains within the intact fibrous capsule [Gorczyca et al., 1997].

Mammary parenchyma: The functional tissue of the mammary gland.

Negative predictive value (NPV): The probability of not having the disease if the result of the test is negative. Formula: TN/(TN + FN).

Periprosthetic: Situated around a prosthesis.

Positive predictive value (PPV): The probability of having the disease if the result of the test is positive. Formula: TP/(TP + FP).

Prosthetic: Relating to a prosthesis, its use or its application.

Sensitivity: The proportion of true positives (TP) in individuals with the disease. Formula: TP/(TP + FN).

Shell: Semipermeable membrane of variable thickness that contains silicone gel and gives the augmented breast a natural appearance and contour. It is made of silicone polymers, which give it its elasticity [Gorczyca et al., 1997].

Silicone: A generic name given to silicium compounds containing oxygen atoms and organic groups. These compounds can exist in various forms, such as oils, resines and elastomers.

Specificity: The proportion of true-negative results (TN) in individuals without the disease. Formula: TN/(TN + FP).

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