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# L'INTELLIGENCE ARTIFICIELLE AU SERVICE DE L'IMAGERIE MAMMAIRE : L'AVÈNEMENT DE LA RADIOMIQUE

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26 octobre 2022

# PLAN DE LA PRÉSENTATION

- Introduction et historique
- La radiomique
- Applications en mammographie
- Applications en échographie mammaire
- Applications en IRM mammaire
- Défis à l'implantation
- Conclusion

# ABRÉVIATIONS

- IA : intelligence artificielle
- CAD : computer-aided detection
- CNN : convolutionnal neuronal network
- DL : deep learning
- IRM : imagerie par résonance magnétique



ELSEVIER

Contents lists available at ScienceDirect

Clinical Radiology



Women's Imaging • Review

Review

## Artificial intelligence

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## AI-enhanced radiology

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## Artificial intelligence

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Epub 2020 Feb 14.

## Introduction to Radiomics

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Affiliations + expand

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Free PMC article

### Abstract

Radiomics is a rapidly evolving field of research concerned with the extraction of quantitative metrics—the so-called radiomic features—within medical images. Radiomic features capture tissue and lesion characteristics such as heterogeneity and shape and may, alone or in combination with demographic, histologic, genomic, or proteomic data, be used for clinical problem solving. The goal of this continuing education article is to provide an introduction to the field, covering the basic radiomics workflow: feature calculation and selection, dimensionality reduction, and data processing. Potential clinical applications in nuclear medicine that include PET radiomics-based prediction of treatment response and survival will be discussed. Current limitations of radiomics, such as sensitivity to acquisition parameter variations, and common pitfalls will also be covered.

**Keywords:** PET; artificial intelligence; machine learning; radiomics; single-photon emission tomography.

**Abstract:** Judgement, as one of the core tenets of medicine, relies upon the integration of multilayered data with nuanced decision making. Cancer offers a unique context for medical decisions given not only its variegated forms with evolution of disease but also the need to take into account the individual condition of patients, their ability to receive treatment, and their responses to treatment. Challenges remain in the accurate detection, characterization, and monitoring of cancers despite improved technologies. Radiographic assessment of disease most commonly relies upon visual evaluations, the interpretations of which may be augmented by advanced computational analyses. In particular, artificial intelligence (AI) promises to make great strides in the qualitative interpretation of cancer imaging by expert clinicians, including volumetric delineation of tumors over time, extrapolation of the tumor genotype and biological course from its radiographic phenotype, prediction of clinical outcome, and assessment of the impact of disease and treatment on adjacent organs. AI may automate processes in the initial interpretation of images and shift the clinical workflow of radiographic detection, management decisions on

## Breast Imaging Limitations

potential applications of artificial intelligence (AI) to breast imaging. The slow or prevent its adoption. Improvement and outcome analyses. In particular, AI can support breast imaging and may be responsible for physicians urgently needed for physicians.

ions, and entertainment sectors, including focus on health care, including AI is directed at the special problems of breast imaging and applications of AI in addressing them. AI is described as “the branch of science dedicated to the develop-

# 1. INTRODUCTION

# POURQUOI L'INTÉRÊT EN IMAGERIE MAMMAIRE?

- Le **cancer du sein** est un problème de santé concernant dans la population
- Beaucoup de données disponibles avec les programmes de dépistage implantés depuis des années (implantation en mai 1998 PQDCS)<sup>1</sup>
- Manque de radiologistes formés en imagerie mammaire, haut taux de dépression<sup>2,3</sup>
- IA se prête bien à un travail d'analyse répétitif avec capacité de gestion de larges bases de données



Statistiques canadiennes estimées sur le cancer du sein (2022)

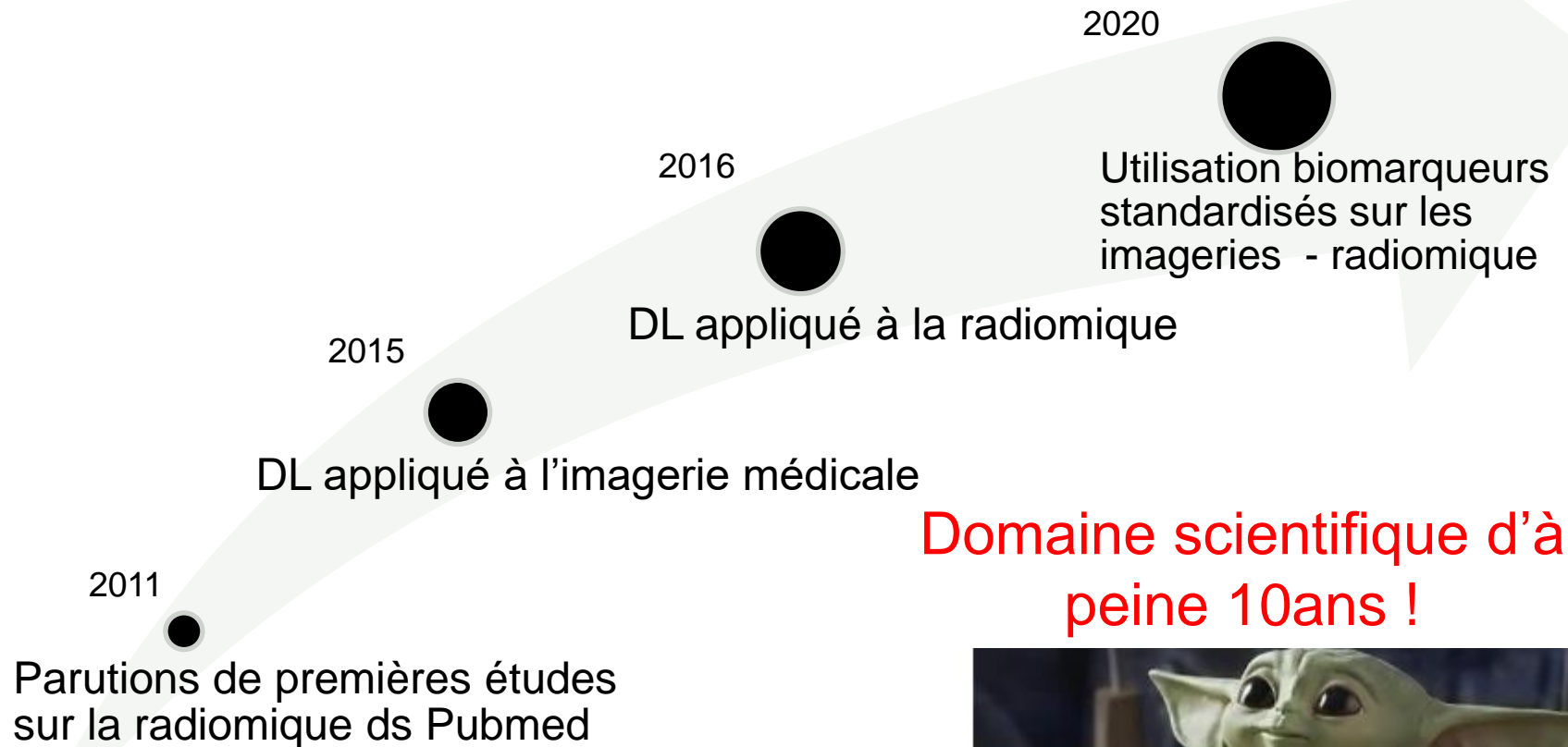
Catégorie	Hommes	Femmes
Nouveaux cas	270	28 600
Décès	55	5 500
Survie nette après 5 ans (estimations de 2015 à 2017)	76 %	89 %

1. <https://cancer.ca/fr/cancer-information/cancer-types/breast/statistics>, octobre 2022

2. P. Wing, M.H. Langelier, Workforce shortages in breast imaging: impact on mammography utilization, Am. J. Roentgenol. 192 (2009) 370–378, <https://doi.org/10.2214/AJR.08.1665>.

3. J.R. Parikh, J. Sun, M.B. Mainiero, Prevalence of burnout in breast imaging radiologists, J. Breast Imag. 2 (2020) 112–118, <https://doi.org/10.1093/jbi/wbz091>.

# UN PEU D'HISTOIRE...



**Domaine scientifique d'à peine 10ans !**







- Différentes innovations dans le domaine médical ces dernières années ; l'intelligence artificielle
- Applications prometteuses au domaine de l'imagerie médicale, qui demande de plus en plus d'investigations complexes et poussées

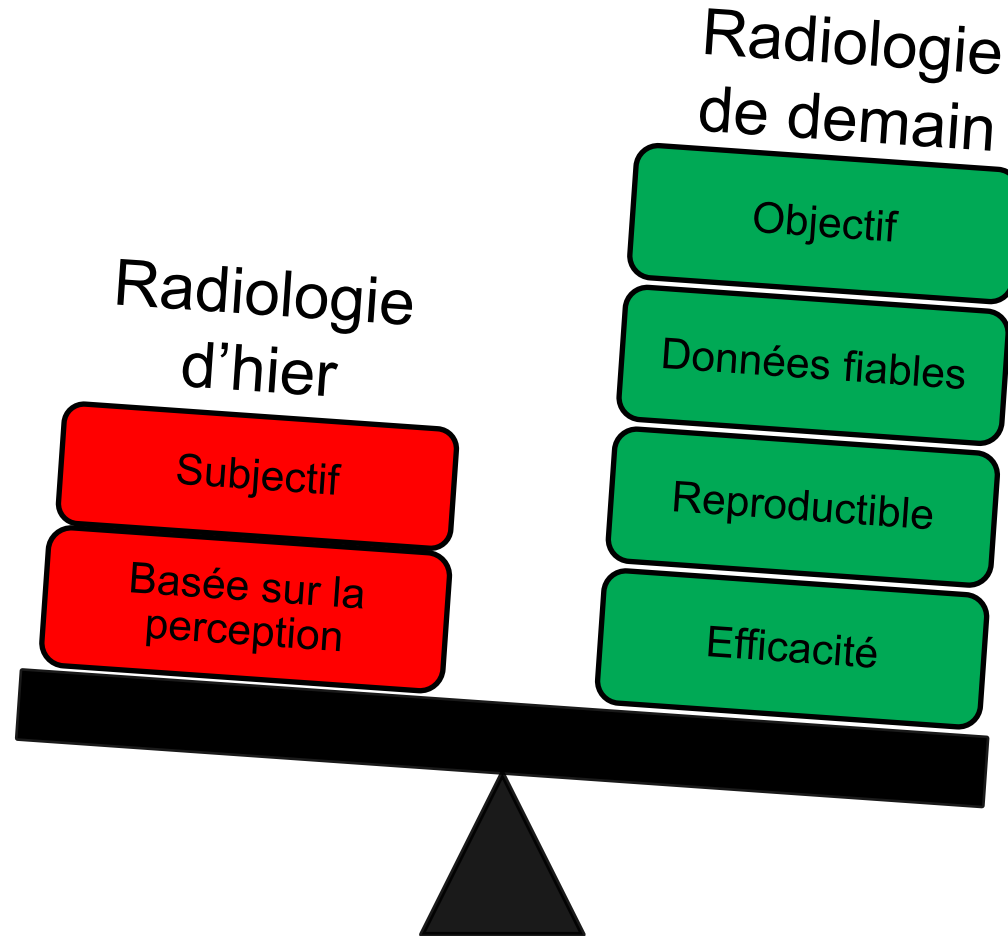




- IA utilisée dans le contexte de **dépistage du cancer du sein** est l'exemple le plus répandu d'application en imagerie
- Utilisation CAD en mammo depuis une décennie, donc bonnes bases pour faire évoluer encore plus loin les possibilités liées à l'IA
- AI permet de d'identifier des trouvaillies non visibles pour l'œil humain...



## L'analyse d'images avec l'aide de l'IA...



## 2. LA RADIOMIQUE

*La **RADIOMIQUE** est une méthode prometteuse permettant, à partir d'un très grand nombre de paramètres quantitatifs extraits d'images radiologiques et confrontés à la réalité clinique et biologique, de découvrir de nouveaux biomarqueurs diagnostiques, pronostiques ou prédictifs.*



Imagerie de la Femme  
Volume 29, Issue 1, March 2019, Pages 25-33



Mise au point

Radiomique : mode d'emploi. Méthodologie et exemples d'application en imagerie de la femme

Radiomics: instructions for use. Methodology and examples of applications in women's imaging

Saskia Vande Perre<sup>a, g, b, c, e</sup>, Loïc Duron<sup>b, c, d</sup>, Audrey Milon<sup>a</sup>, Stéphanie Nougaret<sup>e, f, g</sup>, Laure Fournier<sup>b, c, h</sup>, Isabelle Thomassin-Naggara<sup>a, i</sup>

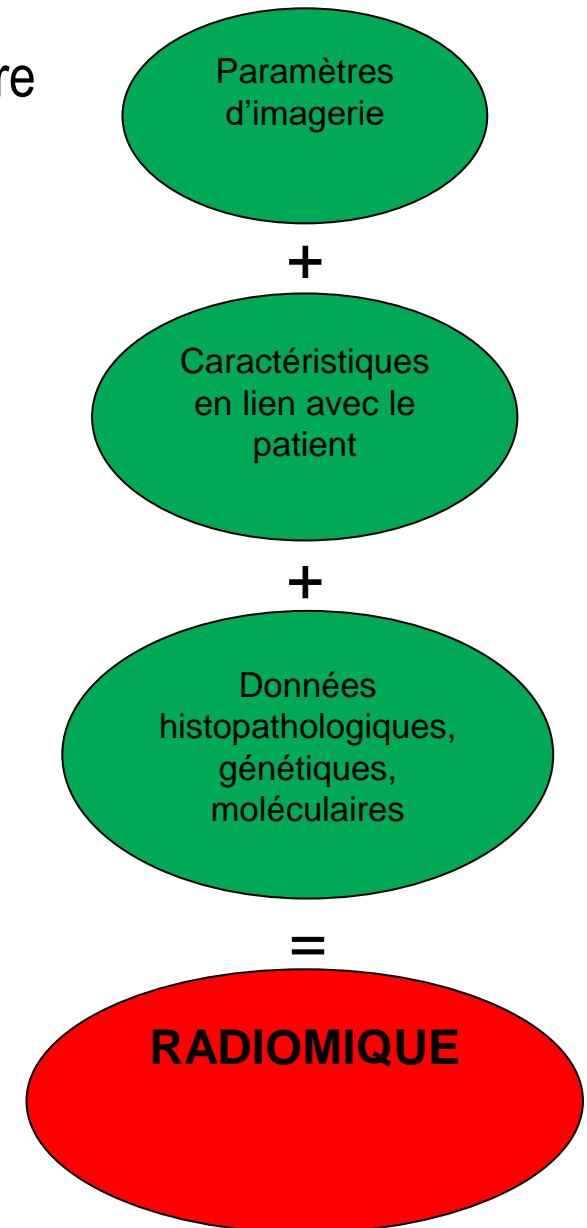
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<https://doi.org/10.1016/j.femme.2019.01.003>

Get rights and content

- Domaine d'étude visant à extraire un grand nombre de donnée avec des algorithmes pour améliorer l'aide à la décision
- Utilise la faculté d'apprentissage de IA



**Table 1**

Main indications for AI-enhanced breast imaging in published studies.

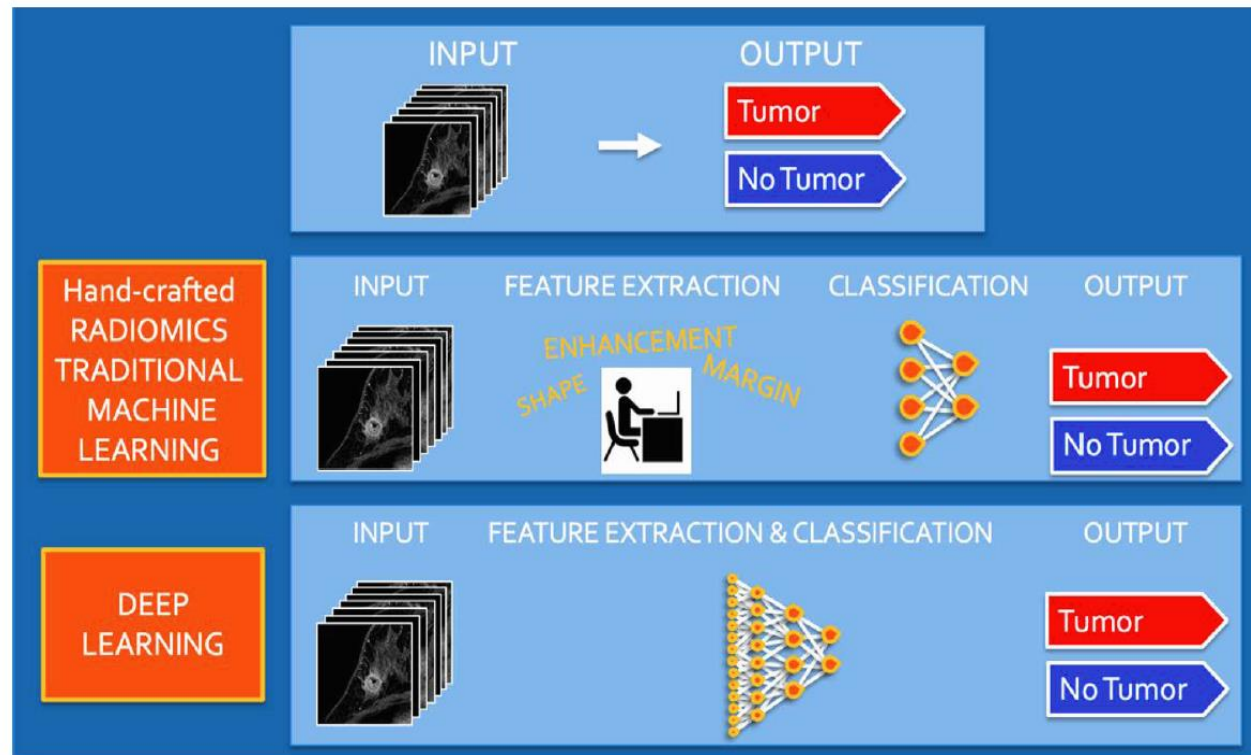
Imaging Method	Indications
Mammography	<ul style="list-style-type: none"> <li>• Screening accuracy and characterization of mammographic lesions [15–22]</li> <li>• Increase screening efficiency (reduce workload) [23–27]</li> <li>• Breast cancer risk prediction [28–32]</li> </ul>
Ultrasound	<ul style="list-style-type: none"> <li>• Differentiation of benign and malignant sonographic lesions [34–44]</li> </ul>
MRI	<ul style="list-style-type: none"> <li>• Automated detection of breast cancer [48–49]</li> <li>• Screening accuracy and characterization of MRI lesions [50–59]</li> <li>• Prediction of breast cancer molecular subtype [60–72]</li> <li>• Prediction of other clinical outcomes (radiogenomics, tumor heterogeneity, lymph node metastasis) [74–78]</li> <li>• Prediction of response to neoadjuvant chemotherapy [79–86]</li> <li>• Prediction of cancer recurrence [87–93]</li> <li>• Breast cancer risk prediction [94]</li> </ul>

## EN RÉSUMÉ, LES PRINCIPALES INDICATIONS:

- Augmenter l'efficacité de lecture
- Prédiction de risque des cancers
- Différenciation entre lésion maligne et bénigne
- Détection automatique
- Possibilité de prédiction sous-type moléculaire
- Prédire la réponse aux traitements



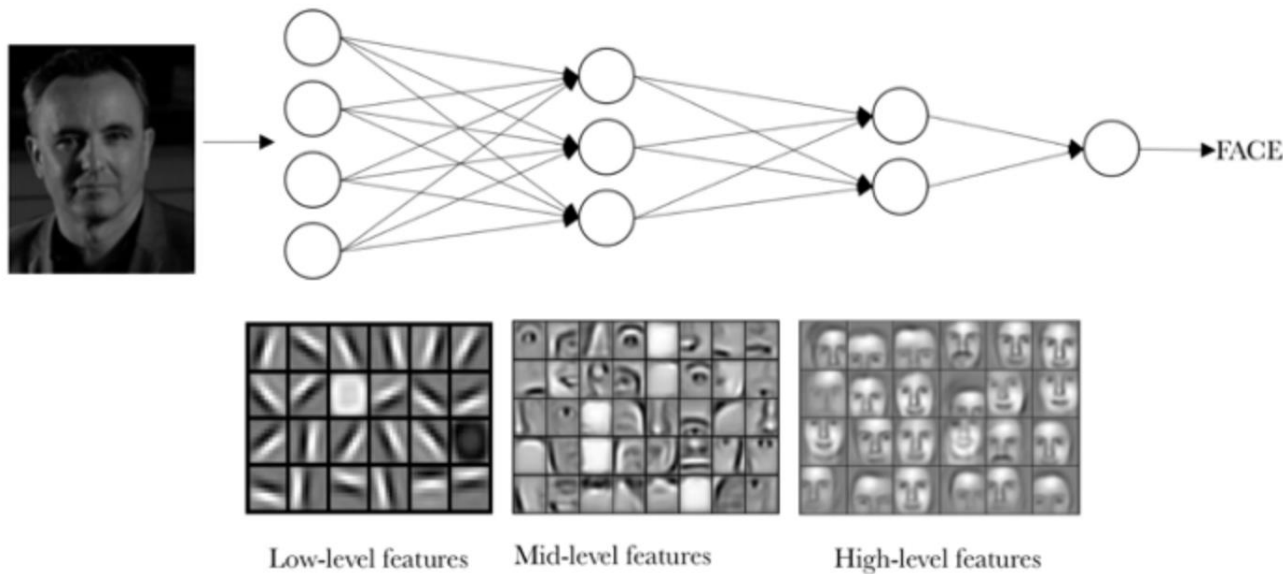
## Traditionnel (manuel) vs à l'aide de IA (DL + CNN)



**Fig. 1.** Radiomics analysis workflow using hand-crafted feature extraction along with traditional machine learning techniques and deep learning for classification and modelling.

# LES RÉSEAUX DE NEURONES À CONVOLUTION

*Depuis les dernières années, les réseaux de neurones convolutionnels (CNNs) sont devenus extrêmement populaires [pour les tâches de segmentation]. Un CNN est un réseau de neurones à propagation avant dans lequel la connectivité entre les neurones s'inspire de la façon dont est organisé le cortex visuel chez l'humain.*



# 3. LA RADIOMIQUE EN MAMMOGRAPHIE

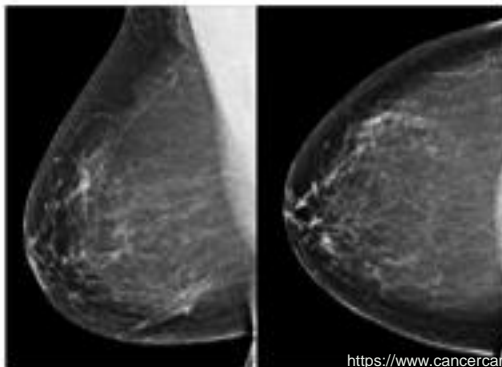
- **Gold standard** dans le dépistage précoce du cancer du sein  
**MAIS**
- Relativement beaucoup de cancer non détecté...

-Sensibilité varie de **75 à 85%**, diminue ++ sein dense (ACR-D)

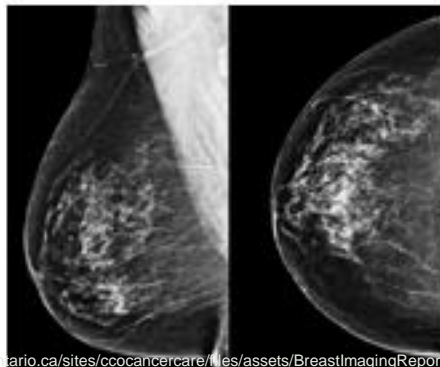
-Faux positifs élevés → nbr de rappels élevé

-Utilisation de IA : augmenter le taux de détection et diminuer le taux de rappel

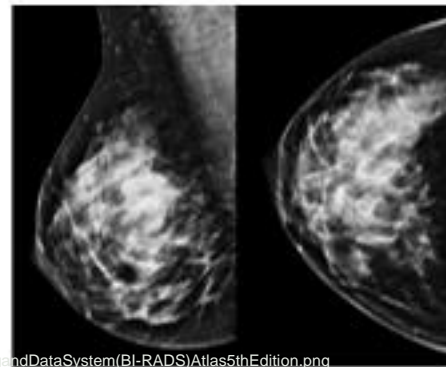
BI-RADS Category A



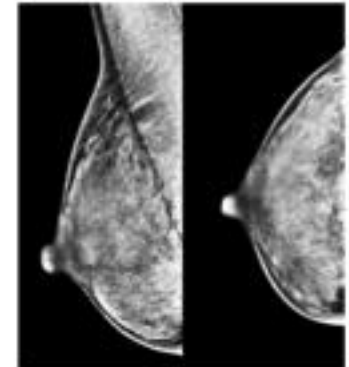
BI-RADS Category B



BI-RADS Category C



BI-RADS Category D



[https://www.cancercareontario.ca/sites/ccocancercare/files/assets/BreastImagingReportingandDataSystem\(BI-RADS\)Atlas5thEdition.png](https://www.cancercareontario.ca/sites/ccocancercare/files/assets/BreastImagingReportingandDataSystem(BI-RADS)Atlas5thEdition.png)

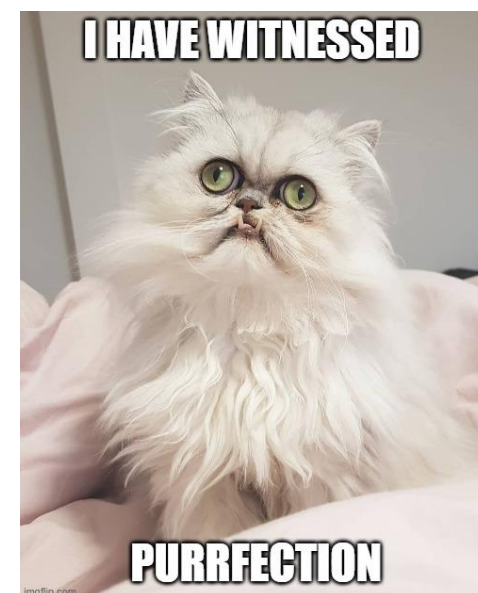
- Utilisation d'un CNN pour **améliorer l'exactitude des examens de dépistage**
    - le meilleur algorithme a réussi une aire sous la courbe de 0.97,8,9
  - Performance de AI en combinaison avec une lecture par des radiologistes est plus précise que les examens analysés par un ou l'autre.
    - résultats sans différence significative entre détection faite par algorithme IA seul ou radiologiste seul
- Versus**
- détection nettement augmentée avec utilisation d'un modèle hybride algorithme + radiologiste

- **Augmenter l'efficacité des dépistages**
  - moins de 1% des examens de dépistage va se terminer en diagnostic de cancer
  - la grande majorité des examens sont donc normaux... beaucoup de temps pour peu de +
- **Pourrait permettre d'éviter des biopsies inutiles de calcifications qui peuvent paraître suspectes (BIRADS 4a-b)**

- **Permettrait une personnalisation des dépistages pour les patientes avec densité mammaire élevée (ACR-D)**

-actuellement, identification subjective de la densité  
-IA est supérieur au radiologue pour déterminer la densité mammaire<sup>10,11</sup>

**Attention par contre...  
l'IA n'est pas  
infaillible... ni le  
radiologue!**



10. H. Sartor, K. Lång, A. Rosso, S. Borgquist, S. Zackrisson, P. Timberg, Measuring mammographic density: comparing a fully automated volumetric assessment versus European radiologists' qualitative classification, Eur. Radiol. 26 (2016) 4354–4360, <https://doi.org/10.1007/s00330-016-4309-3>.

11. B.L. Sprague, E.F. Conant, T. Onega, M.P. Garcia, E.F. Beaber, S.D. Herschorn, C. D. Lehman, A.N.A. Tosteson, R. Lacson, M.D. Schnall, D. Kontos, J.S. Haas, D. L. Weaver, W.E. Barlow, Variation in mammographic breast density assessments among radiologists in clinical practice, Ann. Intern. Med. 165 (2016) 457, <https://doi.org/10.7326/M15-2934>.



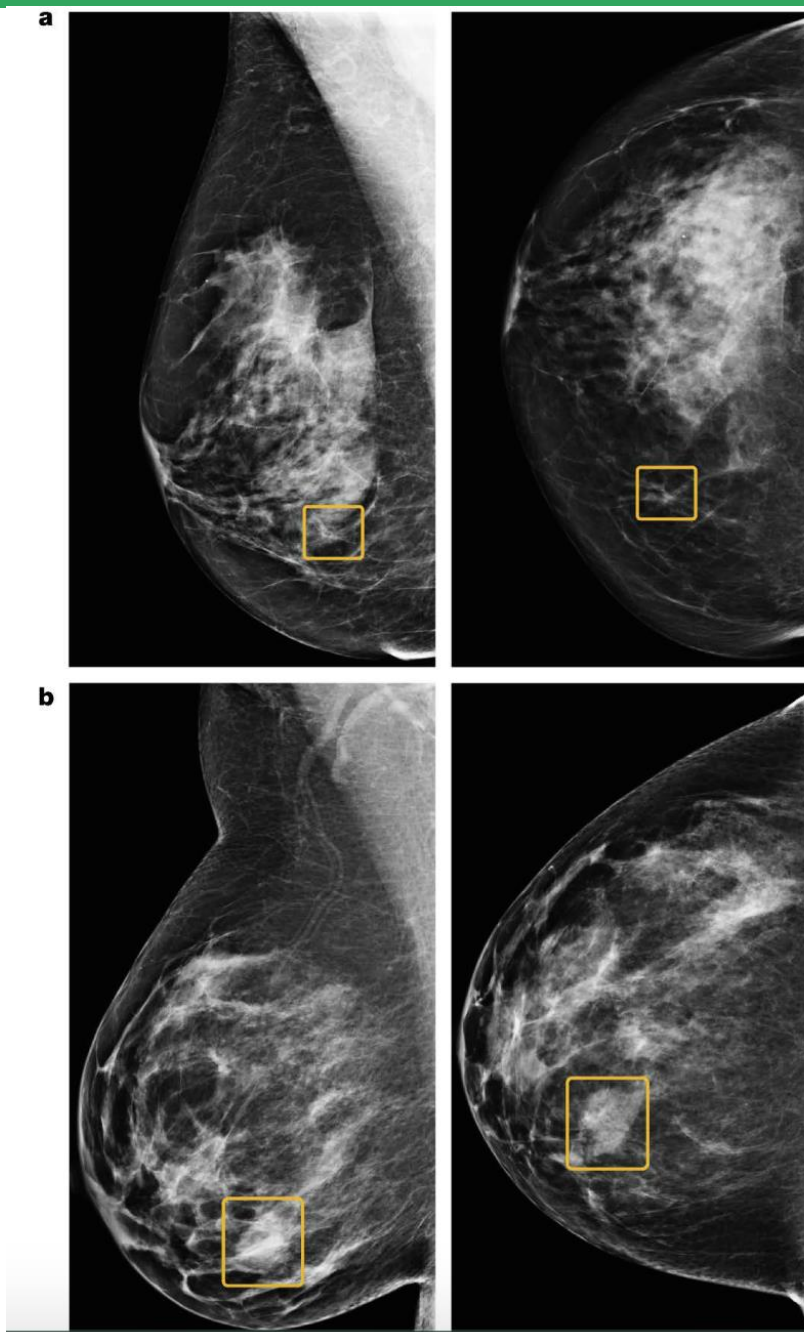
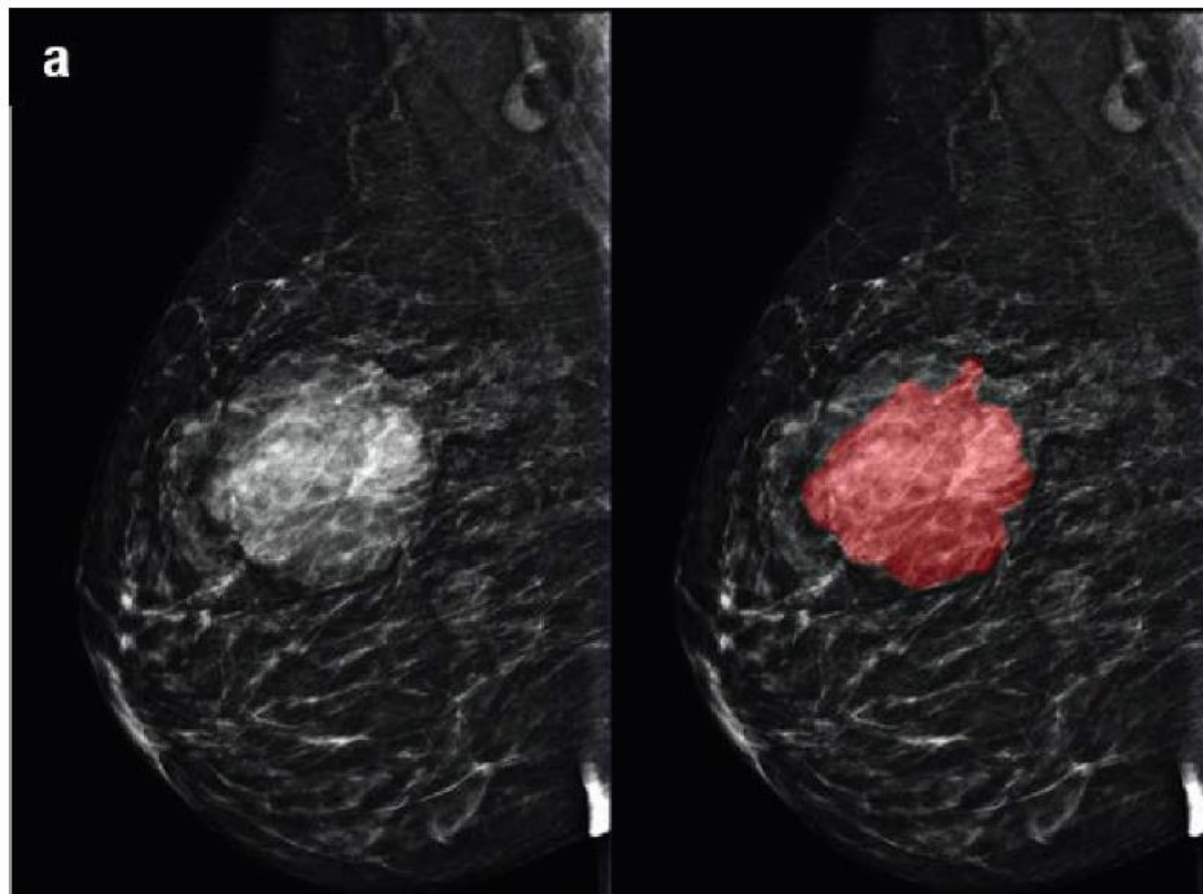
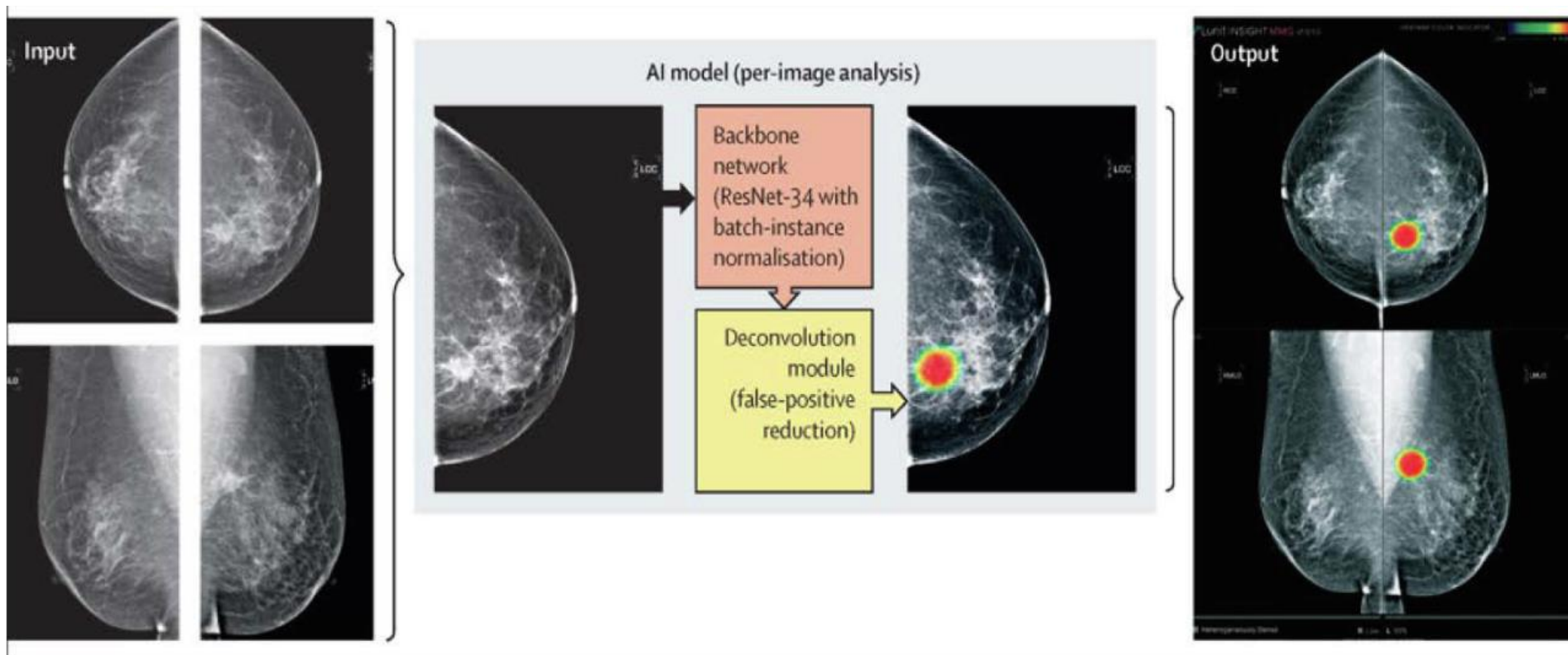


Fig. 4. Discrepancies between the AI system and human readers. (a) A sample cancer case that was missed by all six readers in the US reader study, but correctly identified by the AI system. The malignancy, outlined in yellow, is a small, irregular mass with associated microcalcifications in the lower inner right breast. (b) A sample cancer case that was caught by all six readers in the US reader study, but missed by the AI system. The malignancy is a dense mass in the lower inner right breast. Left, mediolateral oblique view; right, craniocaudal view. Reprinted by permission from Springer Nature Customer Service Centre GmbH: Springer Nature, *Nature*, International evaluation of an AI system for breast cancer screening, S.M. McKinney, M. Sieniek, V. Godbole, et al., 2020. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)



Densité  
Marges  
Taille  
Etc...

Fig. 2. Examples of tumor segmentation on a large mass in the right breast at (a) mammography



diagnostic support software. Reprinted under a Creative Commons Attribution 4.0 International (CC BY-NC-ND 4.0) from: H.-E. Han, H. Nam, E.H. Lee, E.-K. Kim, Changes in cancer detection and false-positive recall in mammography using artificial intelligence: a cohort study, *Lancet Digit. Heal.* 2 (2020) e138–e148. [https://doi.org/10.1016/S2589-7500\(20\)30003-0](https://doi.org/10.1016/S2589-7500(20)30003-0).

# 4. LA RADIOMIQUE EN ÉCHOGRAPHIE MAMMAIRE

- **Départager les lésions bénignes et malignes**

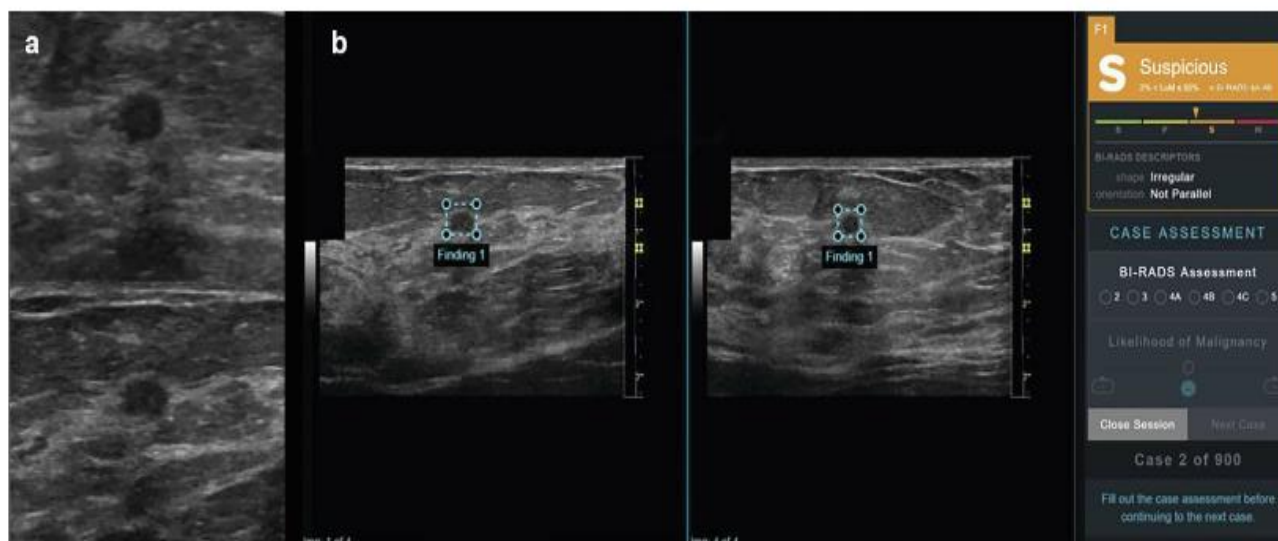
- plus sensible que la mammographie pour la détection de cancer
- spécificité demeure plus faible que mammo, surtout pour les 50ans +

MAMMOGRAPHY		ULTRASOUND	
Breast composition	a. The breasts are almost entirely fatty b. There are scattered areas of fibroglandular density c. The breasts are heterogeneously dense, which may obscure small masses d. The breasts are extremely dense, which lowers the sensitivity of mammography	Tissue composition (screening only)	a. Homogeneous background echotexture – fat b. Homogeneous background echotexture – fibroglandular c. Heterogeneous background echotexture
Masses	Shape Oval Round Irregular Margin Circumscribed Obscured Microlobulated Indistinct Spiculated Density High density Equal density Low density Fat-containing	Masses	Shape Oval Round Irregular Orientation Parallel Not parallel Margin Circumscribed Not circumscribed - Indistinct - Angular - Microlobulated - Spiculated
Calcifications	Typically benign Skin Vascular Coarse or "popcorn-like" Large rod-like Round Rim Dystrophic Milk of calcium Suture Suspicious morphology Amorphous Coarse heterogeneous Fine pleomorphic Fine linear or fine-linear branching Distribution Diffuse Regional Grouped Linear Segmental	Calcifications	Calcifications in a mass Calcifications outside of a mass Intraductal calcifications Architectural distortion Duct changes Skin changes Skin thickening Skin retraction Edema Vascularity Absent Internal vascularity Vessels in rim Elasticity assessment Soft Intermediate Hard
Architectural distortion		Associated features	
Asymmetries	Asymmetry Global asymmetry Focal asymmetry Developing asymmetry	Special cases	Simple cyst Clustered microcysts Complicated cyst Mass in or on skin Foreign body including implants Lymph nodes – intramammary Lymph nodes – axillary Vascular abnormalities AVMs (arteriovenous malformations/pseudoaneurysms) Mandor disease Posturgical fluid collection Fat necrosis
Intramammary lymph node			
Skin lesion	Solitary dilated duct		
Associated features	Skin retraction Nipple retraction Skin thickening Trabecular thickening Axillary adenopathy Architectural distortion Calcifications		
Location of lesion	Laterality Quadrant and clock face Depth Distance from the nipple		

Les lésions présentent différentes caractéristiques selon leur malignité, avec corrélation élevée à la pathologie

- Par exemple, **lésion Birads 4**
- maligne : lobulations, faible entropie
- bénigne : calcif interne, plus large que haut
- IA meilleure pour ces lésions pour l'exactitude du diagnostique





**Fig. 5.** (a) 75-year-old woman with invasive ductal carcinoma. Orthogonal ultrasound transverse (top) and sagittal (bottom) images of 0.4-cm breast mass that could be categorized as oval and parallel and interpreted as benign or probably benign by reader. (b) 75-year-old woman with invasive ductal carcinoma. Artificial intelligence decision support (DS) output scores were presented to study readers in graphical form as electronic case report form in conjunction with orthogonal ultrasound images of lesion for that case. Right panel shows categoric assessment, in this case “suspicious,” with triangle marker indicating confidence of assess-

ment within that category. In this example, DS support correctly classifies this lesion as suspicious; malignancy (invasive ductal carcinoma) was confirmed by ultrasound-guided biopsy. LoM = likelihood of malignancy, B = benign, P = probably benign, S = suspicious, M = probably malignant. Reprinted by permission from V.L. Mango, M. Sun, R.T. Wynn, R. Ha, Should We Ignore, Follow, or Biopsy? Impact of Artificial Intelligence Decision Support on Breast Ultrasound Lesion Assessment, *Am. J. Roentgenol.* 214 (2020) 1445–1452. <https://doi.org/10.2214/AJR.19.21872>.

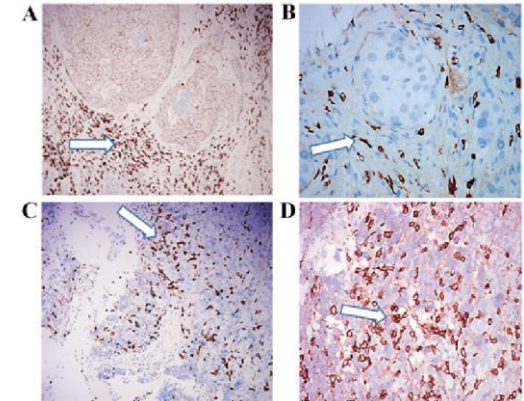
# 5. LA RADIOMIQUE EN IRM MAMMAIRE



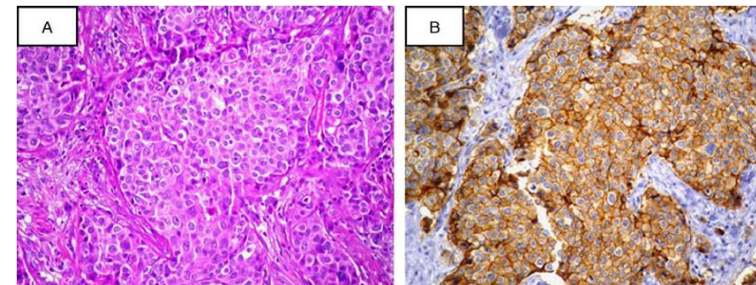
- **Sensibilité élevée pour la détection de cancer**
  - En particulier les lésions infracentimétriques et les rehaussement non masse
- **Biomarqueurs**
  - identification des sous-types moléculaires
  - signature radiomique sur irm avec contraste dynamique
  - avenue intéressante pour les facteurs pronostiques

- Réponse aux traitements de chimiothérapie néoadjuvante
- Prédire la récurrence des cancers

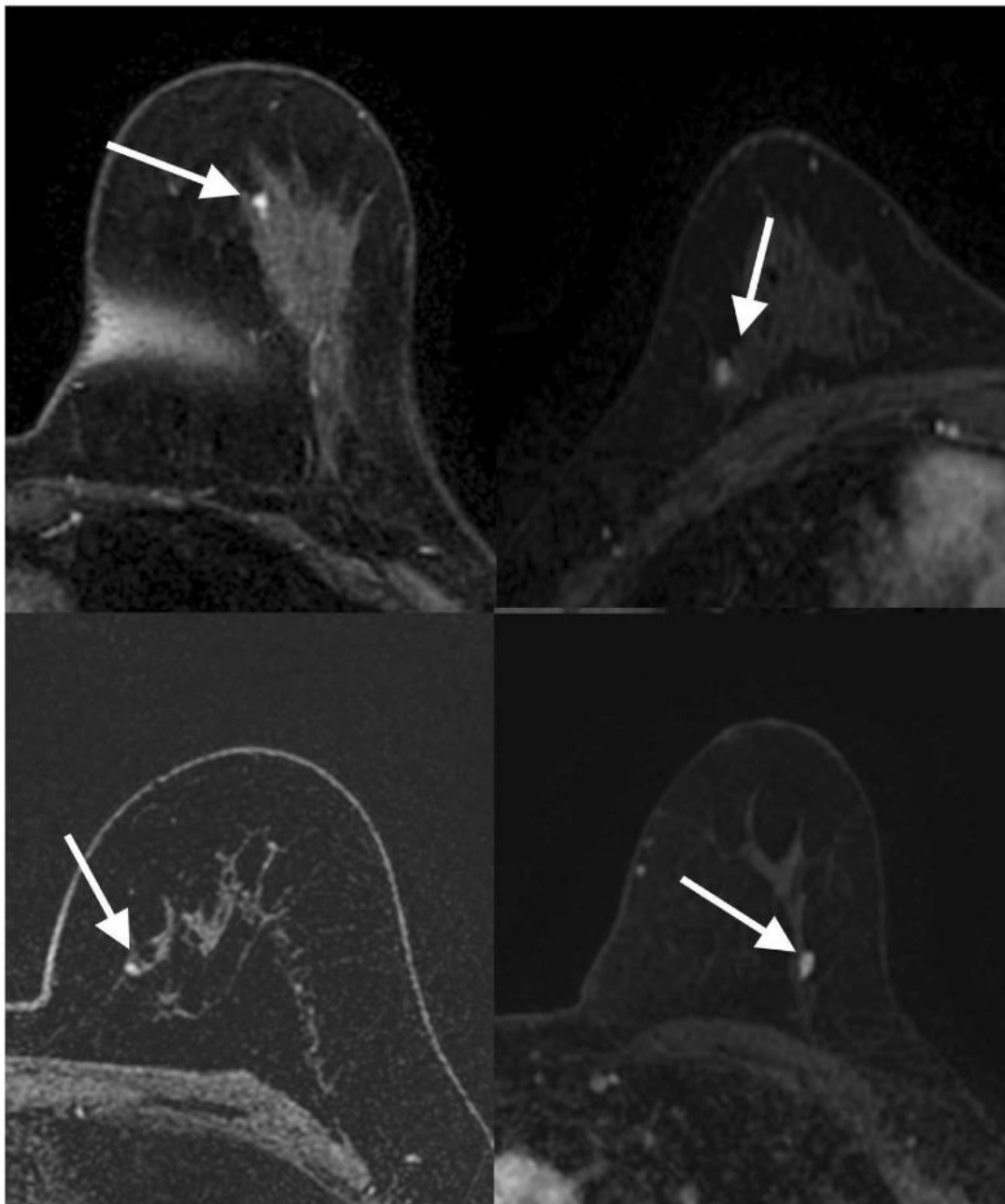
**Néoplasie *Luminal B* et *HER2* présentent des caractéristiques radiomiques distinctes des autres cancers**



[https://www.researchgate.net/figure/Representative-image-of-a-luminal-B-breast-cancer-tissue-sample-with-CD8-TIL\\_fig2\\_316844881](https://www.researchgate.net/figure/Representative-image-of-a-luminal-B-breast-cancer-tissue-sample-with-CD8-TIL_fig2_316844881)



[https://www.researchgate.net/figure/Example-of-HER2-positive-breast-cancer-tumor-IHC-3-and-HER2-CEP17-ratio-22-by-FISH\\_fig2\\_268232500](https://www.researchgate.net/figure/Example-of-HER2-positive-breast-cancer-tumor-IHC-3-and-HER2-CEP17-ratio-22-by-FISH_fig2_268232500)



**Fig. 6.** Transverse first post-contrast bilateral dynamic MR images (TR/TE, 4.5/2.1 ms; flip angle, 10°) of four patients with benign-appearing small breast masses (white arrows) in which biopsy yielded invasive ductal carcinoma. Reprinted under a Creative Commons Attribution 4.0 International (CC BY 4.0) from: R. Lo Gullo, I. Daimiel, C. Rossi Saccarelli, A. Bitencourt, P. Gibbs, M.J. Fox, S.B. Thakur, D.F. Martinez, M.S. Jochelson, E.A. Morris, K. Pinker, Improved characterization of sub-centimeter enhancing breast masses on MRI with radiomics and machine learning in BRCA mutation carriers, *Eur. Radiol.* 30 (2020) 6721–6731.

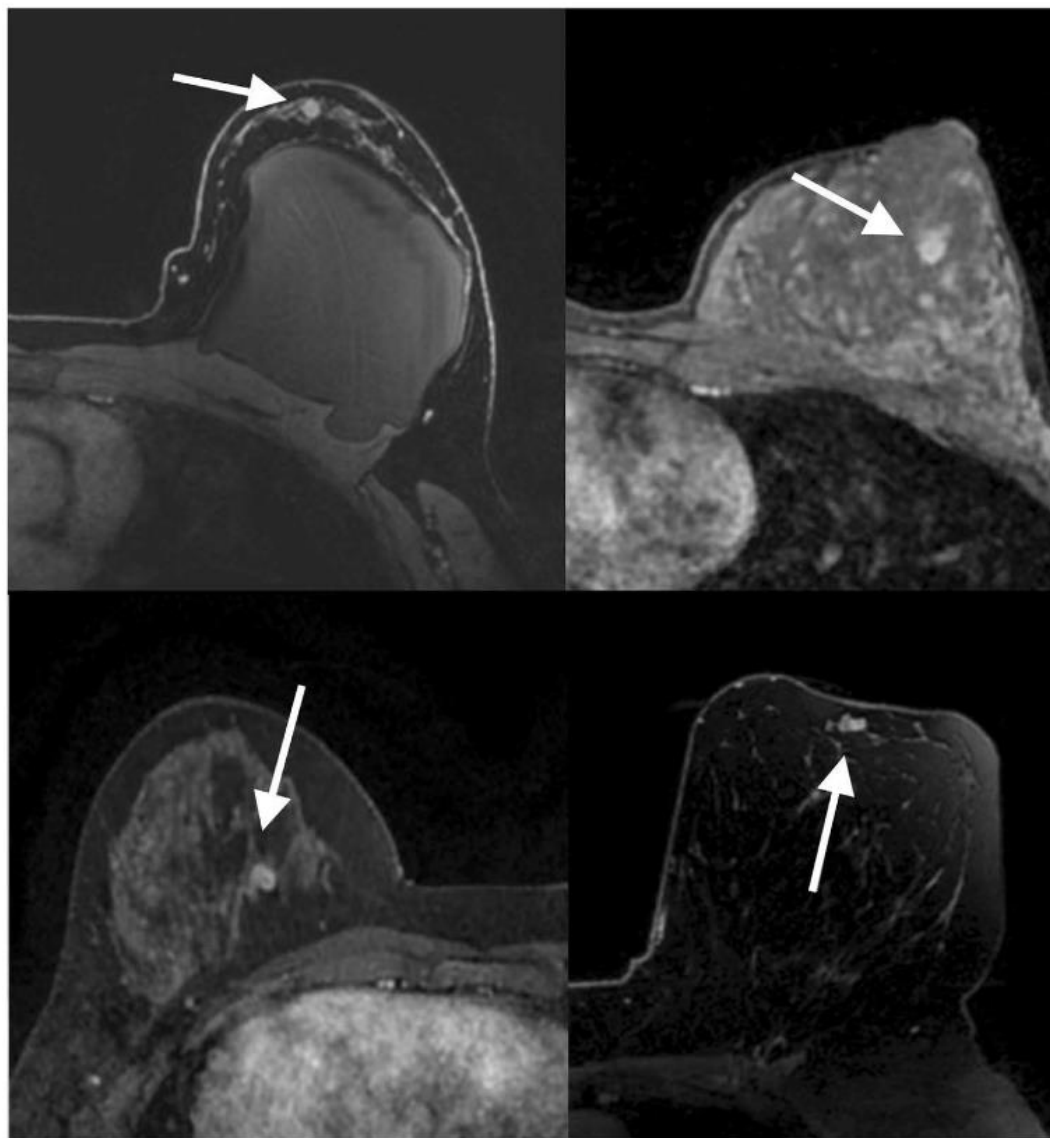
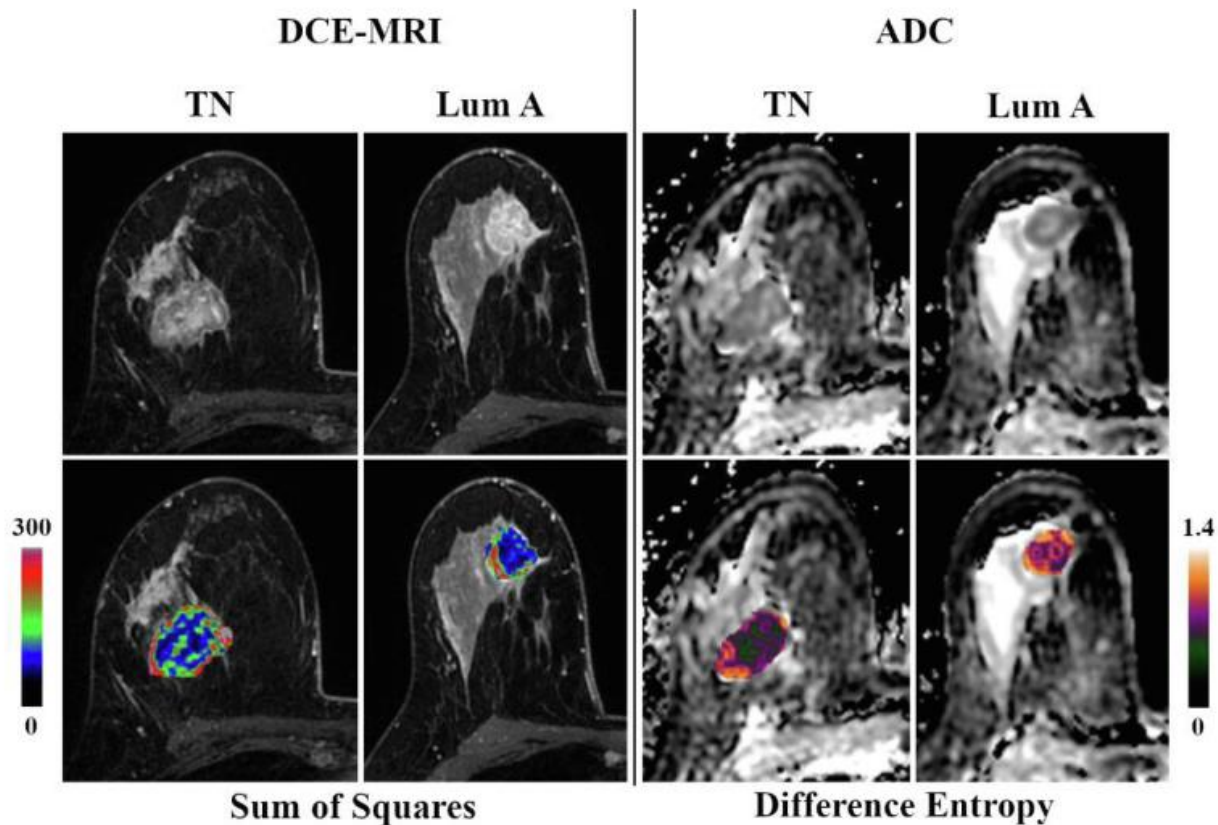
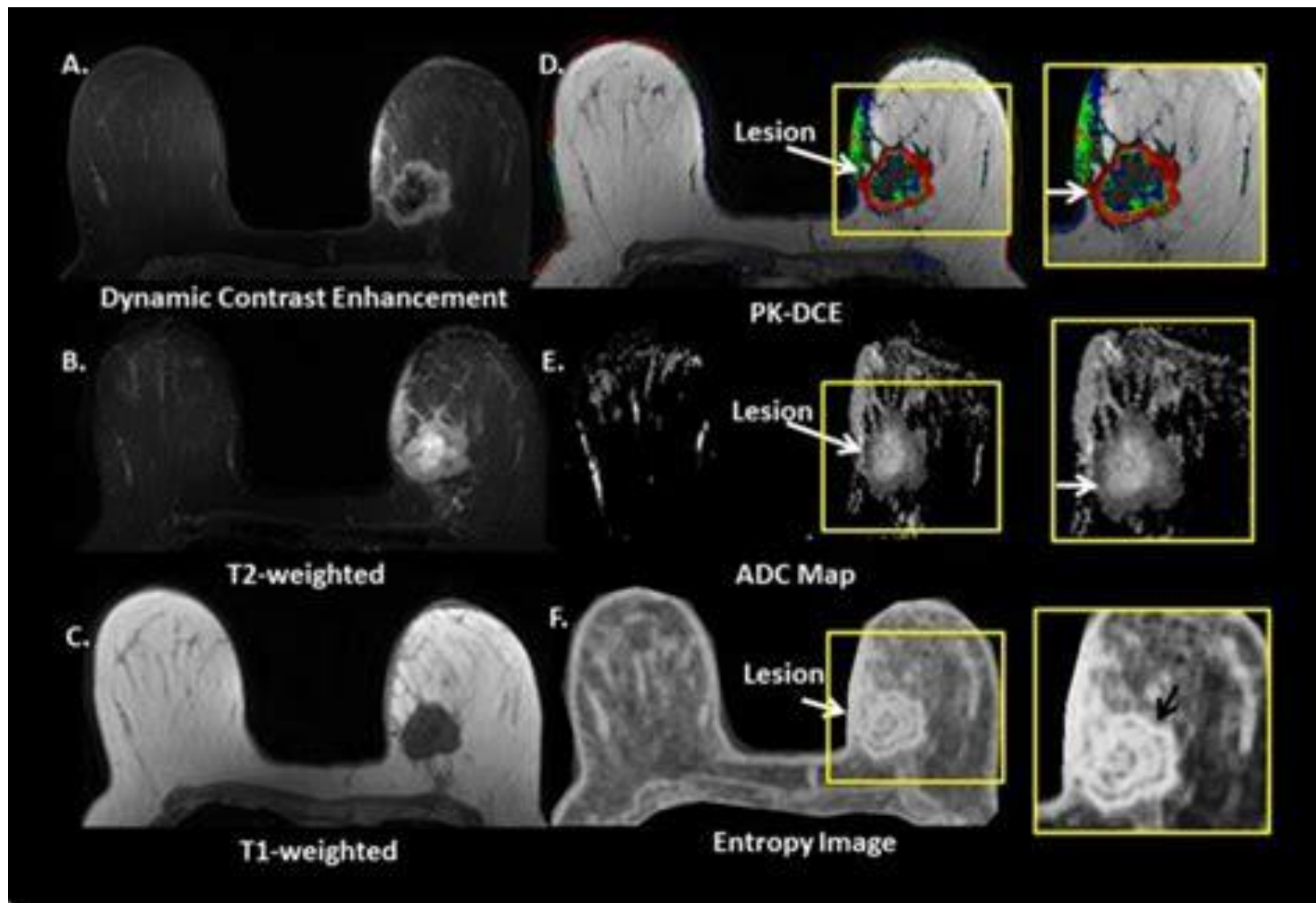


Fig. 7. Transverse first post-contrast bilateral dynamic MR images (TR/TE, 4.5/2.1 ms; flip angle, 10°) of four patients with suspicious-appearing small breast masses categorized as BI-RADS 4 in which biopsy results yielded fibroadenoma (white arrows) and pseudoangiomatous stromal hyperplasia (white arrow). Reprinted under a Creative Commons Attribution 4.0 International (CC BY 4.0) from: R. Lo Gullo, I. Daimiel, C. Rossi Saccarelli, A. Bitencourt, P. Gibbs, M.J. Fox, S.B. Thakur, D.F. Martinez, M.S. Jochelson, E.A. Morris, K. Pinker, Improved characterization of sub-centimeter enhancing breast masses on MRI with radiomics and machine learning in BRCA mutation carriers, *Eur. Radiol.* 30 (2020) 6721–6731.



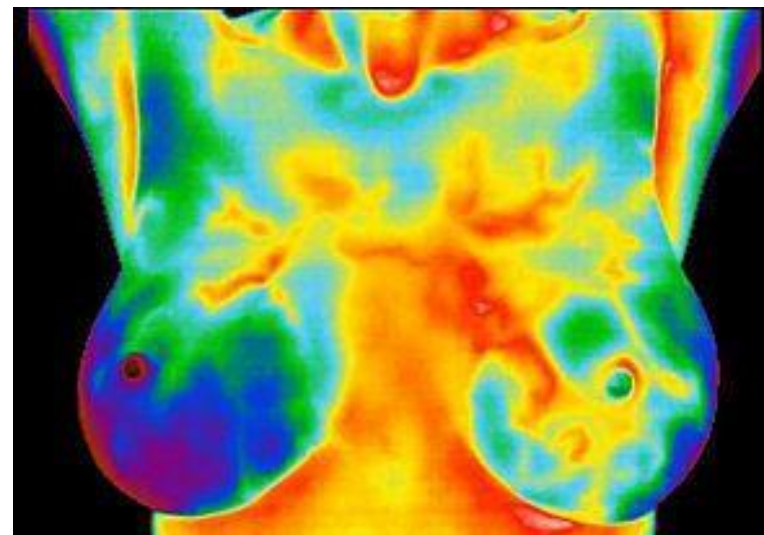
**Fig. 8.** Original DCE-MRI images/ADC maps and corresponding color-coded feature maps as overlays of the tumor area of triple negative (TN) and luminal A breast cancer. Reprinted under a Creative Commons Attribution 4.0 International (CC BY 4.0) from: D. Leithner, M.E. Mayerhoefer, D.F. Martinez, M.S. Jochelson, E.A. Morris, S.B. Thakur, K. Pinker, Non-Invasive Assessment of Breast Cancer Molecular Subtypes with Multiparametric Magnetic Resonance Imaging Radiomics, *J. Clin. Med.* 9 (2020) 1853.





## 6. LIMITATIONS

- Défi principal à l'implantation des différentes techniques d'IA :
  - manque de standardisation
  - rareté d'études à grandes échelles (faible échantillon surtout IRM... coût/temps d'utilisation)
- Pas de protocole standardisé pour IRM mammaire
- Particulièrement au Québec... accessibilité à l'IRM restreinte, certain retard sur le plan des nouvelles technologies

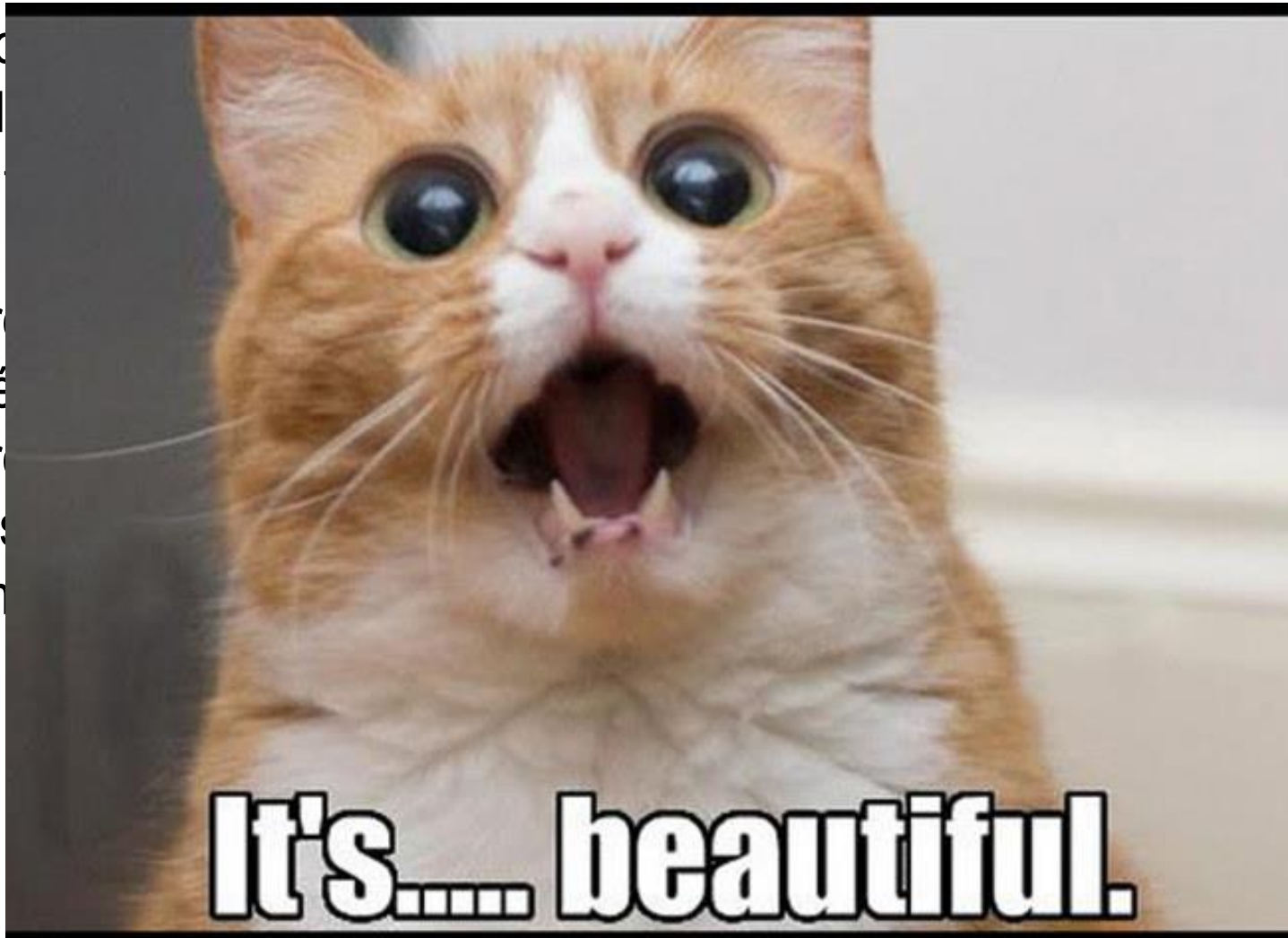




# 7. CONCLUSION

Le do  
rapid  
sont

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**SI LA RADIOMIQUE A SEMÉ UN INTÉRÊT EN VOUS...  
OU POUR INITIER DE NOUVELLES PERSONNES AU  
SUJET :**

[HTTPS://WWW.YOUTUBE.COM/WATCH?V=LLPIAHLMLG](https://www.youtube.com/watch?v=LLPIAHLMLG)

[HTTPS://WWW.YOUTUBE.COM/WATCH?V=6GIVIXMCZFU](https://www.youtube.com/watch?v=6GIVIXMCZFU)

**MERCI!**

**QUESTIONS/COMMENTAIRES?**