INTELLIGENT HEALTH SYSTEMS AND EMERGING MEDICAL RESEARCH

ISPEC INSTITUTE

INTELLIGENT HEALTH SYSTEMS AND EMERGING MEDICAL RESEARCH- 2026

ISBN: 978-625-92238-8-9

DOI: 10.5281/zenodo.19845725

April / 2026

Ankara / Türkiye

(The Licence Number of Publicator: 2014/31220)

E mail: info@ispecbooks.com

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ISPEC Publishing House – 2026©

ISBN: 978-625-92238-8-9

April / 2026

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PREFACE

This volume brings together a collection of scholarly contributions that explore emerging developments in healthcare systems, medical technology, and interdisciplinary health sciences. As contemporary medicine continues to evolve, the integration of ethical frameworks, intelligent technologies, and alternative biological resources has become increasingly significant in improving healthcare delivery and innovation.

The chapters in this book address key themes related to modern health systems and medical research. The examination of Sharia Maqashid within healthcare institutions highlights the importance of value-based and culturally responsive service models. The discussion on deep learning and radiomic analysis demonstrates the transformative potential of artificial intelligence in breast cancer imaging, diagnosis, and predictive medicine. In addition, the assessment of medicinal insects reflects the growing relevance of biodiversity and traditional biological resources in therapeutic and pharmaceutical research.

By adopting an interdisciplinary perspective, this volume integrates insights from health sciences, artificial intelligence, medical imaging, and integrative medicine. It contributes to academic discourse while also offering practical implications for healthcare professionals, researchers, and policymakers seeking innovative and inclusive approaches to health services.

It is hoped that this book will serve as a valuable resource for scholars, practitioners, and students interested in healthcare innovation, intelligent diagnostics, and interdisciplinary medical sciences, while encouraging further research at the intersection of technology, culture, and medicine.

Editorial Team
April, 2026
Türkiye

CHAPTER 1
INTEGRATION OF SHARIA MAQASHID IN THE HEALTH SERVICE SYSTEM: A QUALITATIVE STUDY IN INDONESIAN SHARIA HOSPITALS

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INTRODUCTION

Sharia maqashid is a fundamental concept in Islamic law that emphasizes that every sharia provision has the main purpose of realizing benefits (maslahah) and preventing damage (mafsadah) in human life. This concept is not only normative but also has a broad philosophical and practical dimension in various areas of life. Historically, the maqashid sharia was developed by classical scholars such as Al-Ghazali and refined by Al-Syatibi through the formulation of the five main purposes of sharia, namely to preserve religion (hifzh al-din), to preserve the soul (hifzh al-nafs), to preserve reason (hifzh al-'aql), to preserve posterity (hifzh al-nasl), and to preserve property (hifzh al-mal). These five goals are known as al-kulliyat al-khamsah, which are the basis for formulating policies and practices in human life, including in the field of health. In this context, maqashid sharia provides an ethical and normative framework that is able to bridge between religious values and the practical needs of modern humans, making it relevant to be integrated into the public service system, including health services (Adesty, 2025).

In contemporary developments, maqashid sharia is no longer understood narrowly as a legal concept alone, but has developed into a multidisciplinary approach that can be applied in various sectors, such as economics, education, law, and health. This approach emphasizes the importance of substance rather than formality, so that the implementation of sharia is not only measured by compliance with the rules, but also by the extent to which the goals of sharia are achieved. In the context of health services, maqashid sharia can be the foundation for designing a service system that is not only oriented towards curing diseases, but also improving the quality of human life as a whole, both physically, mentally, and spiritually.

Thus, the integration of sharia maqashid in health services is a need that cannot be ignored in an effort to create a just and sustainable health system. (Siregar, 2024).

The health sector is one of the most strategic areas in the application of sharia maqashid, especially in the aspect of life protection (hifzh al-nafs), which is the main priority in the maqashid hierarchy. Hospitals as health service institutions have a great responsibility in maintaining the safety, health, and welfare of patients. From an Islamic perspective, health services are not limited to medical measures, but also include aspects of disease prevention, health promotion, and maintaining a balance between physical and spiritual. Therefore, the integration of sharia maqashid in health services is essential to ensure that every medical procedure performed is not only clinically effective, but also in accordance with Islamic ethical and moral values (Sulistiadi, W. Sulistiadi & Rahayu, S. Rahayu, 2017).

The development of sharia hospitals in Indonesia has shown a significant trend in recent years. This is in line with the increasing awareness of the Muslim community on the importance of health services in accordance with Sharia principles. Sharia hospitals are present as an alternative that offers integration between modern medical standards and Islamic values, such as halal medical products, ethical services, and attention to the spiritual needs of patients. In addition, the existence of sharia hospitals is also supported by regulations and certifications issued by related institutions, thereby providing quality assurance and compliance with sharia principles. This phenomenon shows that the integration of religious values in health services is not only a spiritual need, but also part of a competitive healthcare development strategy. (Yuhanah et al., 2024).

The implementation of sharia maqashid in sharia hospitals in Indonesia still faces various challenges that are quite complex. One of the main problems is the tendency of symbolic implementation, where the label "sharia" emphasizes the administrative aspect rather than the substance of the maqashid values themselves. This can be seen from the limited integration of the maqashid principle in the decision-making process, patient service, and overall hospital management. This condition shows that there is still a gap between the ideal concept of sharia maqashid and practice in the field that requires more serious attention from various parties (Masnur et al., 2025).

In addition to institutional factors, the human resource aspect is also an important challenge in the implementation of Sharia maqashid in hospitals. Medical personnel and other health workers have a strategic role in realizing sharia-based health services. However, not all health workers have an adequate understanding of the concept of sharia maqashid, so its implementation is often not optimal. The lack of training and socialization about Sharia values in health services is one of the factors that affect this condition. Therefore, efforts are needed to increase the capacity of human resources through continuous education and training so that the integration of sharia maqashid can run effectively. (Sulistiadi, W Sulistiadi & Rahayu, S Rahayu, 2017).

The integration of sharia maqashid in health services can be realized through various forms of concrete implementation. For example, the provision of worship facilities for patients and families, the use of halal medicines, and services that pay attention to Islamic ethics and manners. In addition, the communication approach between medical personnel and patients is also an important aspect in reflecting the values of maqashid sharia, such as honesty, empathy, and respect for human dignity.

This implementation shows that maqashid sharia is not only conceptual, but can also be internalized in daily service practices in Hospitals. (Mui Natıonal Syarıah Councıl, 2016).

The application of sharia maqashid in health services also has a positive impact on service quality and patient satisfaction levels. Hospitals that are able to comprehensively integrate Sharia values tend to have a competitive advantage compared to conventional hospitals. This is because patients not only get quality medical services, but also feel the spiritual comfort that is part of the healing process. Thus, the integration of sharia maqashid can be an effective differentiation strategy in increasing the competitiveness of hospitals in the era of globalization. (Syaifullah, 2024).

The qualitative approach is a relevant method in examining the integration of sharia maqashid in the health service system. This is because the qualitative approach allows researchers to delve deeply into experiences, perceptions, and practices that occur in the field. Through this method, researchers can understand how the concept of sharia maqashid is interpreted and implemented by various parties, including hospital management, medical personnel, and patients. In addition, the qualitative approach also allows the identification of factors that affect the success and obstacles in the implementation of sharia maqashid (Masnur et al., 2025).

Research on the integration of sharia maqashid in health services in Indonesia is still relatively limited, especially those that use empirical and qualitative approaches. Most of the existing research focuses more on the Islamic economic and financial sectors, while the health sector has not received adequate attention. In fact, the health sector has a very important role in realizing the welfare of the community as a whole.

Therefore, this chapter is expected to fill the gap and contribute to the development of science, especially in the field of Sharia economics and management (Masruroh, 2025).

Studies on the integration of sharia maqashid in the health service system in Indonesian sharia hospitals are very important and relevant to be carried out. This chapter aims not only to analyze the implementation of sharia maqashid but also to identify the various challenges and opportunities that exist in its development. This chapter is expected to be the basis for policy formulation and the development of health service practices that are more holistic, equitable, and oriented towards the benefit of the people. In addition, this chapter is also expected to make a practical contribution to hospital managers in improving the quality of sharia-based services. (Yuhanah et al., 2024).

1. CONCEPTUALIZATION OF SHARIA MAQASHID IN THE HEALTH SERVICE SYSTEM

Sharia maqashid is a fundamental concept in Islamic law that emphasizes that every sharia provision has the purpose of realizing benefits (maslahah) and preventing damage (mafsadah). Historically, this concept was formulated by Al-Ghazali and then systematized by Al-Syatibi in the form of five main goals (al-kulliyat al-khams), namely the protection of religion (hifz al-din), the soul (hifz al-nafs), reason (hifz al-'aql), heredity (hifz al-nasl), and property (hifz al-mal). In contemporary developments, maqashid is understood not only as a normative framework, but also as a multidisciplinary paradigm that can be applied in various sectors, including the modern healthcare system ((Masnur et al., 2025). In the context of health, the Sharia maqashid places Hifz al-NAFS (Life Protection) as the most central goal. This shows that maintaining health is not just a biological need, but part of a religious and social obligation.

As explained by Arrizky et al. (2023), health is the main prerequisite for humans to carry out the function of worship and social activities optimally, so the health service system must be designed to ensure the survival and quality of human life. Thus, health services from the perspective of maqashid are not only curative, but also preventive and promotive. (Arrizky et al., 2023).

Maqashid sharia offers an approach Teleological (goal-oriented) approach, which assesses a system based on its ultimate goal. In the healthcare system, this approach shifts the orientation from simply fulfilling procedural standards to value-based healthcare. This means that the success of health services is not only measured from the clinical aspect, but also from the dimensions of ethics, spirituality, and social justice. This approach is in line with the research of Haque et al. (2024), which affirms that the integration of maqashid in the health system can improve the sustainability of services and the welfare of the community as a whole. (Haque et al., 2024).

The structure of Sharia maqashid is divided into three levels of needs: Dharuriyat, Hajiyat, and Tahsiniyat, which provide a priority framework in the implementation of health services. At the dharuriyat level, the main focus is on saving lives through emergency services and critical illness treatment. At the hajjat level, the health system must be able to reduce people's difficulties through access to affordable and equitable services. Meanwhile, at the tahsiniyat level, services are directed to improving quality, such as patient comfort, service ethics, and respect for human values (Aulia et al., 2025). This structure is important in formulating fair and efficient health policies.

In the operational framework, the sharia maqashid functions as Evaluative Tools (Maqasid 'Ammah) in assessing health service policies and practices.

For example, aspects of patient safety and quality of service reflect the implementation of hifz al-nafs, while cost transparency and fairness of access reflect hifz al-mal. In fact, protection of the psychological aspect of the patient can also be associated with hifz al-'aql. Thus, maqashid is a comprehensive indicator in assessing the success of the health service system holistically. (Masnur et al., 2025).

The conceptualization of sharia maqashid in Indonesia is the basis for the development of sharia hospitals. Sharia-based hospitals are not only medically service-oriented, but also integrate Islamic spiritual values and ethics in every aspect of service. For example, the existence of worship facilities, spiritual assistance for patients, the use of halal medicines, and the application of polite and empathetic service ethics. This shows that maqashid sharia functions as an integrative framework between medical aspects and religious values in health services. (Azis et al., 2025).

Several studies show that the implementation of sharia maqashid in health services still faces various challenges. One of the main challenges is the tendency to formalize, where institutions focus only on fulfilling administrative aspects and labeling "sharia" without internalizing the substantial value of maqashid. This phenomenon is also found in the Islamic finance sector, where formal compliance is often more dominant than the achievement of the substantive goals of the maqashid (Masnur et al., 2025). This shows the need for a more comprehensive approach in integrating maqashid into the healthcare system.

The development of science and technology, including the digitalization of health services, opens up new opportunities in strengthening the implementation of sharia maqashid.

The dynamic and adaptive approach of maqashid, as developed by Jasser Auda, allows the integration of sharia values in modern innovations such as telemedicine, health information systems, and sharia-based health insurance. This shows that the Sharia maqashid has the flexibility to answer the challenges of the times while maintaining the fundamental values of Islam. (Auda, 2021).

The conceptualization of sharia maqashid in the health service system emphasizes that health is an integral part of the sharia goal in realizing human welfare. The integration of maqashid values allows for the creation of a health service system that is not only medically effective, but also fair, ethical, and welfare-oriented. Therefore, sharia maqashid can be used as an alternative paradigm in the development of a sustainable and humanist health system, especially in a Muslim-majority country like Indonesia.

The strengthening of the conceptualization of sharia maqashid in the health service system can also be understood through an integrative approach between normative values and empirical practice. In this regard, the Sharia maqashid not only serves as an ethical framework but also as a strategic instrument in the formulation of inclusive and social justice-oriented health policies. This approach emphasizes that every health policy and service must be able to reach all levels of society without discrimination, and pay attention to sustainability aspects in the long term. In addition, the integration of sharia maqashid also encourages innovation in the health service system, such as the development of community-based services, increasing public health literacy, and strengthening the disease prevention system. Thus, maqashid sharia is not only a theoretical foundation, but also an operational paradigm that is adaptive to the dynamics of modern health needs (Auda, 2021).

2. IMPLEMENTATION OF SHARIA MAQASHID IN SHARIA HOSPITAL SERVICE PRACTICE IN INDONESIA

The implementation of sharia maqashid in the practice of sharia hospital services in Indonesia shows a significant transformation from a normative concept to an applicative operational system. (Sulistiadi et al., 2025). Sharia maqashid is no longer only understood as a philosophical principle, but has been internalized in various aspects of health services, from clinical services to hospital governance. This transformation shows that Islamic values are able to be integrated concretely in the modern health system. This is in line with the findings in the study that affirm that sharia maqashid functions as a strategic framework in improving the quality of health services through the integration of medical and spiritual dimensions, thereby creating more holistic and patient-centered services. (Hayati et al., 2025).

The implementation of sharia maqashid in clinical service practices that focus on life protection (hifz al-nafs) through improving the quality of medical services and patient safety. Sharia hospitals in Indonesia adopt an approach patient-centered care approach, which puts the patient as the main subject of the service. This approach pays attention not only to the clinical aspect, but also to the emotional and spiritual needs of the patient. Thus, health services are no longer mechanical but more humane and comprehensive. Recent research shows that the integration of maqashid values in clinical services can improve patient satisfaction and strengthen the relationship between medical personnel and patients (Aulia et al., 2025).

The integration of spiritual aspects is an important part of the practice of Sharia hospital services. The implementation of sharia maqashid is reflected in the provision of integrated spiritual services, such as spiritual guidance, worship assistance, and psychological support based on Islamic values.

This service plays a role in maintaining a balance between the physical and spiritual health of patients, which is the hallmark of Sharia hospitals. In this context, the Sharia maqashid not only protects the physical aspect, but also the spiritual aspect of the human being. Research shows that the existence of spiritual services is the main indicator in the sharia hospital service system and is a significant differentiator compared to conventional hospitals. (Yuhanah et al., 2024).

The implementation of sharia maqashid is also seen in pharmaceutical services and patient consumption. Sharia hospitals ensure the halalness of medicines and food through the selection process of medical ingredients and food management according to halal principles. This is directly related to the protection of religion (hifz al-din) while maintaining the quality of patient health. With the halal guarantee, public trust in Sharia hospital services is increasing. Studies show that the implementation of halal standards in healthcare is an important factor in increasing patient satisfaction and loyalty (Mardiyati, 2021).

The implementation of sharia maqashid is also reflected in the ethics of health workers. Medical personnel are required to apply Islamic values such as empathy, honesty, maintaining patient privacy, and providing services without discrimination. These values not only improve the quality of service but also form a more harmonious relationship between patients and medical personnel. Thus, sharia hospitals are not only technically superior, but also morally and ethically. Research shows that maqashid-based service ethics are able to increase patient trust and strengthen the image of hospitals as humanist and religious institutions. (Fakhri et al., 2025). The implementation of sharia maqashid in a broader context also touches on aspects of hospital management and governance.

Sharia hospitals adopt sharia-based governance principles that include transparency, accountability, and fairness. This system is supported by Sharia audits to ensure that all hospital activities are in accordance with Islamic principles. With good governance, hospitals are not only operationally efficient but also have strong social legitimacy in the community. Research shows that maqashid-based governance is able to improve organizational efficiency while strengthening public trust. (Hayatı, 2025).

The implementation of sharia maqashid is strengthened through the standardization and certification of sharia hospitals carried out by DSN-MUI and MUKISI. This standard covers various aspects, ranging from medical services, spiritual services, to sharia-based financial management. However, the level of implementation of the standard still varies between hospitals, depending on the readiness of human resources and management commitment. This shows that the transformation process towards a sharia hospital still needs to be strengthened in various aspects.

Empirically, the development of Islamic hospitals in Indonesia shows a positive trend. This can be seen from the increasing number of hospitals that adopt sharia principles, along with increasing public awareness of health services based on Islamic values. In addition, the implementation of sharia maqashid has been proven to have a positive impact on patient satisfaction and loyalty of health service users. The following data shows these developments:

Based on the data in Tables 1 and 2, it can be concluded that the development of sharia hospitals in Indonesia has increased significantly, although it is still dynamic. In the early period, especially around 2019, growth began to be seen with around 54 hospitals in the process of Sharia certification.

This is driven by the role of the All-Indonesia Islamic Health Efforts Council and regulations from the National Sharia Council of MUI, which strengthen the operational foundation of sharia hospitals in Indonesia. (Nashrullah, 2019).

Table 1. Statistics of the Development of Sharia Hospitals (2019 - 2024)

Year	Number of Certified/Processed Hospitals	Growth/Key Notes
2019	54 - 60 RS	The massive post-DSN-MUI Fatwa No. 107 has begun.
2020	65 RS	Focus on intensive assistance by MUKISI.
2022	72 RS	Spread from Sabang to Merauke.
2023	103 Health Facilities	It includes 31 fully certified hospitals and 72 are in process.
2024	79 Health Facilities	Data from July 2024 recorded 79 active units (Hospitals, Clinics, & Labs).

This development continues to increase until 2023, when it is recorded that 31 hospitals have been Sharia-certified and 72 others are still in process. This shows that there is an acceleration in the implementation of Sharia principles in the health sector.

This increase is also inseparable from the increasing need for health services based on Islamic values, as well as stronger institutional support in the process of certification and hospital assistance.

Table 2. Comparison with Total Hospitals in Indonesia

Categories	Numerical Data	Remarks
Total hospitals in Indonesia (2024)	2,710 units	The majority are private and public hospitals.
MUKISI Members	Approximately 500 Hospitals	The potential of Islamic hospitals that can switch to Sharia certification.
Sharia Hospital Market Share	2,46% - 5%	This figure shows that the potential for growth is still very large.

Data for 2024 shows that the number of active sharia health service facilities (fasyankes) is in the range of 79 units, which includes hospitals, clinics, and laboratories. These figures show that despite the growth, the implementation of sharia certification still faces challenges in terms of consistency and sustainability. Factors such as the readiness of human resources, compliance with standards, and the sharia audit process determine the success of hospitals in maintaining their sharia status. (Scott, 2024).

When compared to the total number of hospitals in Indonesia, which reaches more than 3,000 units, the market share of Islamic hospitals is still relatively small.

However, there are around 500 Islamic hospitals that are members of the All-Indonesia Islamic Health Efforts Council, which has the potential to transform into a sharia hospital. This shows that the opportunity for the development of this sector is still very large, especially in the context of strengthening the ecosystem of the sharia health industry in Indonesia. (Yuliastuti, 2022).

This growth trend is also closely related to the increasing public awareness of the importance of health services that are not only of medical quality, but also in accordance with Sharia principles. With the majority of Indonesia's population being Muslim, the need for health services based on spiritual values is becoming increasingly relevant. Therefore, the implementation of sharia maqashid in hospitals is not only a normative need, but also a strategy in increasing public competitiveness and trust in Islamic-based health services (Scott, 2024).

The empirical data show that although the contribution of Islamic hospitals to the national health system is still relatively small, their growth trend shows a positive and promising direction. Therefore, a more integrated strategy is needed, such as strengthening regulations, improving the quality of human resources, and optimizing the role of certification bodies so that the great potential of the sharia hospital sector can be utilized optimally in supporting the national health system based on sharia maqashid values.

Although these developments point in a positive direction, the implementation of sharia maqashid in health services still faces a number of obstacles. Among them are the limited number of human resources who have a comprehensive understanding of Sharia principles, the lack of a standard to measure the achievement of maqashid, and the possibility of incompatibility between modern medical practices and religious values.

This condition indicates that the implementation of sharia maqashid requires a flexible and sustainable approach. Therefore, efforts are needed to strengthen by increasing the capacity of professionals, drafting regulations at the national level, and utilizing technology in the development of sharia-based health services. (Yandi et al., 2024).

The implementation of sharia maqashid in sharia hospitals in Indonesia shows that this concept has high relevance in improving the quality of health services. By integrating medical, spiritual, and ethical aspects, maqashid sharia is able to create a health service system that is more holistic, humanistic, and oriented towards community welfare. In the future, strengthening the implementation of sharia maqashid is expected to make sharia hospitals an alternative model of the health system that is not only clinically superior but also has high moral and spiritual value.

To provide a more systematic overview of how the principles of sharia maqashid are implemented in sharia hospital services, the following is presented a mapping between the goals of maqashid, the form of implementation, and examples of practices carried out in health services.

Based on the table above, it can be understood that each principle of sharia maqashid has a concrete form of implementation in the sharia hospital service system. This shows that the values of maqashid sharia are not only conceptual, but can also be operationalized in various aspects of services, ranging from medical services, health, education, to financial management.

Table 3. Integration of Sharia Maqashid in Sharia Hospital Services

The Principles of Maqashid	Implementation in Sharia Hospitals	Example Practice
Hifdz ad-Din	Worship facilities & spiritual services	Musholla, spiritual guidance
Hifdz an-Nafs	Quality medical services	Patient safety standards
Hifdz al-Aql	Health education	Counseling & counseling
Hifdz an-Nasl	Mother & child care	Shariah-compliant childbirth
Hifdz al-Mal	Islamic finance	Cost transparency, usury-free

The integration reflects the efforts of Sharia hospitals in providing services that are not only oriented towards curing diseases, but also towards meeting the spiritual, social, and economic needs of patients. Thus, the application of sharia maqashid is an important foundation in creating comprehensive and equitable health services, and is able to improve the quality of life of patients as a whole.

3. IMPACTS, CHALLENGES, AND MODELS FOR STRENGTHENING THE INTEGRATION OF SHARİA MAQASHID

The integration of sharia maqashid in the healthcare system in Indonesian sharia hospitals has brought about a fundamental paradigmatic change in the way healthcare services are designed, managed, and delivered to patients. This approach no longer places health solely as a curative effort against disease, but as part of an effort to maintain the sustainability of human life as a whole, which includes physical, spiritual, social, and moral aspects.

From the perspective of sharia maqashid, health services are instruments to achieve benefits (maslahah) and prevent damage (mafsadah), so the entire service process must be directed at the protection of the five main aspects of human life. This is strengthened by the finding that a maqashid-based health system is able to contribute to improving people's welfare and supporting sustainable health development (Haque et al., 2024).

The integration of maqashid sharia seen from the impact on patients has been proven to be able to significantly improve the quality of the health service experience. Patients not only receive professional medical services, but also receive spiritual and emotional support in accordance with their religious values. The presence of worship facilities, halal food services, and a polite and empathetic communication approach are important factors in building patient comfort. Research shows that elements such as an Islamic environment, sharia-compliant hospital policies, and humanistic and religious attitudes of health workers are the main determinants in improving patient satisfaction (Harun & Senawi, 2023).

The integration of sharia maqashid also has an impact on increasing patient loyalty and public trust in sharia hospitals as superior health service institutions. This can be seen from the positive correlation between the quality of halal-based services and a high level of patient satisfaction. Empirical studies show that the majority of patients in sharia hospitals express a very high level of satisfaction, which directly influences their decision to return to using the service as well as recommend it to others (Irasanti et al., 2022).

In addition to external impacts, the integration of sharia maqashid also has a significant influence on the internal aspects of the hospital organization, especially in the formation of work culture.

Values such as trust, honesty, responsibility, and service as a form of worship are the foundation of the behavior of health workers. This creates a more ethical, collaborative, and service-oriented work environment. In this context, the application of sharia principles has been proven to be able to improve the quality of hospital management and strengthen the relationship between medical personnel and patients. (Ardian et al., 2023).

The implementation of the integration of sharia maqashid is inseparable from various structural and cultural challenges. One of the main challenges is the limited human resources that have an integrative understanding between medical science and Sharia principles. Many health workers have high clinical competence, but do not have an adequate understanding of Sharia maqashid. This condition causes the implementation of sharia values in service practice to be often not optimal and tends to be symbolic (Astiwara, 2024).

Another taboo that is no less important is the lack of comprehensive standards and indicators to measure the success rate of the implementation of sharia maqashid in health services. Although some countries have developed sharia indices in the health sector, these indicators are still general and have not been able to measure the specific dimensions of maqashid in health service practices. This causes difficulties in conducting evaluations and comparisons between institutions and hinders the development of evidence-based policies (Ismail & Mutalib, 2022).

Challenges also arise from aspects of the national health system that have not fully supported the integration of sharia principles, especially in terms of financing and regulation. Health insurance systems that are still conventionally based are often not fully in line with Sharia principles, thus creating a dilemma in the implementation of maqashid as a whole.

Research shows that the incompatibility between the health financing system and sharia principles can be an obstacle in the development of sharia hospitals in Indonesia (Minarni et al., 2025).

To overcome these challenges, a comprehensive and sustainable model of strengthening the integration of sharia maqashid is needed. One approach that can be done is through strengthening the capacity of human resources through education and training based on sharia maqashid. This program must be systematically designed to integrate medical aspects and sharia values, so that health workers have complete competencies. In addition, the role of the sharia supervisory board also needs to be strengthened to ensure compliance with sharia principles in all aspects of hospital operations. (Indriani & Yanova, 2024).

Another strengthening model is the development of an indicator and evaluation system based on sharia maqashid that is able to measure hospital performance more comprehensively. These indicators should include the dimensions of service quality, patient satisfaction, sharia compliance, and the social impact of health services. With a measurable evaluation system, the implementation of sharia maqashid can be carried out more systematically and sustainably. Research shows that the development of halal and sharia-based hospital indicators is an important step in improving the quality of services and institutional accountability. (As-salafiyah, 2022).

The integration of sharia maqashid as a whole in the health service system in Indonesian sharia hospitals has great potential to become an alternative model of a health system that is more humane, ethical, and sustainable. By combining modern medical science and sharia values, sharia hospitals can provide services that are not only medically effective but also spiritually meaningful.

In the future, with the strengthening of human resources, regulations, and evaluation systems, the integration of sharia maqashid is expected to be able to become the main paradigm in the development of a national health system that is oriented towards the benefit of the people as a whole (Imaniyati et al., 2025).

Strengthening the integration of sharia maqashid can also be done through a collaborative approach between various stakeholders, including the government, educational institutions, health professional organizations, and religious institutions. This inter-stakeholder synergy is very important in building a strong and sustainable sharia healthcare ecosystem. Universities, for example, have a strategic role in developing a health education curriculum that integrates medical science with Sharia maqashid values. Thus, health care workers graduate not only with clinical competence, but also with adequate ethical and spiritual understanding. Research shows that cross-sectoral collaboration in the development of value-based health systems can improve the effectiveness of policy implementation and strengthen the overall quality of health services. (Haque et al., 2024).

The use of digital technology is also one of the important strategies in strengthening the integration of sharia maqashid in health services. Digital transformation, such as the use of telemedicine, electronic medical records, and Sharia-based health information systems, can increase the efficiency, transparency, and accessibility of health services. This technology also allows for more effective supervision of sharia compliance in hospital operations. Recent studies show that digitalization in the health system not only improves the quality of services but can also be aligned with the principles of sharia maqashid in safeguarding the welfare of the community at large (Aulia et al., 2025).

CONCLUSION

The integration of sharia maqashid in the health service system in Indonesian sharia hospitals is a relevant and strategic approach in creating holistic, humanistic, and equitable health services. The concept of sharia maqashid which is oriented towards benefit (maslahah) and damage prevention (mafsadah) has proven to be able to be a normative as well as operational foundation in the development of health services that not only focus on clinical aspects, but also include spiritual, ethical, and social dimensions. Conceptually, the sharia maqashid provides a comprehensive framework through five main goals (al-kulliyat al-khams), namely the protection of religion, soul, intellect, descent, and property. In the context of health services, the principle of hifz al-nafs is a top priority that is reflected in efforts to improve the quality of medical services and patient safety. However, the simultaneous integration of these five principles allows for the creation of a more comprehensive health service system oriented towards improving the quality of human life. This chapter shows that the implementation of sharia maqashid in Indonesian sharia hospitals has undergone significant developments, both in the aspects of clinical services, spiritual services, halal pharmaceutical management, health worker ethics, and institutional governance. This integration not only increases patient satisfaction and loyalty, but also strengthens public trust İn sharia-based health services. Thus, sharia maqashid can be a source of competitive advantage for hospitals in the midst of increasingly complex competition in the health sector. However, the implementation of sharia maqashid still faces various challenges, including the limitation of human resources who comprehensively understand sharia principles, the tendency to formalize without substance, the absence of standardized evaluation indicators, and the lack of optimal support for the national health system, especially in terms of regulation and financing.

These challenges show that the integration of sharia maqashid requires a more systematic, sustainable, and collaborative approach.

Therefore, a strengthening model is needed that includes increasing the capacity of human resources through maqashid-based education and training, the development of sharia-based health service performance indicators, strengthening the role of sharia supervisory institutions, and the use of digital technology in supporting service efficiency and transparency. In addition, collaboration between the government, educational institutions, professional organizations, and religious institutions is key in building a sustainable ecosystem of Sharia health services.

Overall, the integration of sharia maqashid in the health service system has great potential to become an alternative paradigm in the development of a national health system that is not only medically superior but also based on ethical and spiritual values. With the right strengthening, Islamic hospitals in Indonesia can develop into a health service model that is oriented towards the benefit of the people as a whole and able to answer global challenges in the future.

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CHAPTER 2
DEEP LEARNING ANALYSIS OF RADIOMIC HETEROGENEITIES AND TUMOR MICROENVIRONMENTS: TOWARDS THE IDENTIFICATION OF IMAGING FACTORS FAVORING BREAST CANCER TUMORIGENESIS AND AGGRESSIVENESS

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INTRODUCTION

Worldwide, breast cancer represents a massive public health challenge. In 2022, it was estimated that there were 2.3 million new breast cancer diagnoses among women, with approximately 670,000 deaths from breast cancer in the same year (Hussain et al., 2024). Screening mammography has established nearly 30% reduction in breast cancer mortality from early detection over the last three decades. However, high costs, false-positive findings and overdiagnosis have led to extensive controversy concerning the use of age-based screening programmed. As a result, the practice of medicine is moving toward developing personalized breast cancer screening programmed based on individual risk assessment for each patient.

Traditional risk assessment uses a variety of demographic, clinical and genetic parameters. One of the most established biomarkers for breast density is BI-RADS breast density classifications; that is, women with greater breast density experience a substantial change in the likelihood of developing breast cancer compared with women with low breast density (Lotter et al., 2024). However, the density alone has limited capabilities to capture the overall breast cancer prognosis captured within the breast image. Studies have demonstrated the significant added prognostic value of deep learning analysis of the texture pattern of breast parenchyma to assess breast cancer risk beyond that of breast density (Lotter et al., 2024). Additionally, breast cancer is biologically heterogeneous, both inter- and intratumor, and has been shown to be a primary driver of breast cancer aggressiveness and clinical outcome (Radiomics in breast cancer, 2024).

In the last several years, AI and particularly deep learning has begun to provide unprecedented opportunities for providing quantitative analyses of images acquired by medical imaging tools.

Recently, a systematic review of the literature was completed to evaluate the application of deep learning techniques to digital mammography, radiomics, genomics, and clinical data for breast cancer risk assessment (Hussain et al., 2024). Deep learning methodologies are capable of extracting minute visual features (signatures) from medical images that are undetectable by the human eye and that represent risk factors associated with malignant lesions. In fact, deep learning techniques are able to directly predict certain established tumor characteristics from mammographic imaging and tomosynthesis, yielding promising results for molecular subtyping, nodal staging, and prognosis (Mota, 2025). These advances indicate that many of the previous paradigms (based primarily on detection of lesions) will involve identifying imaging markers associated with the emergence and progression.

The analysis of perilesional regions has also demonstrated considerable promise in providing useful information. Recent research has demonstrated that perilesional and intra-lesional radiomics (combined with deep transfer learning) from dynamic contrast-enhanced MRI have the ability to discriminate benign from malignant lesions, with an AUC of 0.950 during internal validation and a 0.921 during external validation, which significantly exceed the performance of highly trained radiologists (Integrating intra-tumoral and peritumoral radiomics, 2024). Furthermore, adding perilesional edema data to deep learning-based radiomic models has shown significant improvements in predicting the burden of axillary lymph node metastasis (Peritumoral edema enhances MRI-based deep learning radiomic model, 2024). Together, these findings substantiate the premise that imaging manifestations of disease within the tumor microenvironment contain important prognostic information. In addition, longitudinal data from multiple screening tests represents a significant advancement in the field of dynamic risk modeling.

Unlike most deep learning models that only take into account a single screening test, recent architectures are being developed to use multiple mammograms to observe the temporal changes in the breast's tissue. An example of this is the LongiMam model which combines two networks (convolutional and recurrent) and shows that systematically incorporating prior exams with new exams can improve predictions over time, especially in women who have experienced changes in breast density over time (Rakez et al., 2025). The MTP-BCR model which incorporates traditional risk factors and longitudinal data accomplished an AUC of 0.80 for predicting risk over a 10-year period, significantly better than predictive models that only utilize information from one-time points (Predicting short- to long-term breast cancer risk, 2025). Other models utilize a Transformer architecture to identify the spatiotemporal asymmetries between both breasts to refine prediction of risk over a 1–5-year period (STA-Risk, 2025).

Using multiple data modalities to fuse imaging, genomic, histopathological, and clinical biomarkers is another area being explored for improving the predictive capability of risk models. Using multimodal deep learning models to combine radiomic, deep feature, and RNA-Seq data, researchers have achieved internal AUCs of 97.8% for BI-RADS classification demonstrating multimodal approaches have superior predictive capability relative to their unimodal counterparts (Feature fusion in a multimodal deep learning framework, 2025; Transformer-based multi-modal learning, 2025). However, these types of models remain rare today, and external validation of the predictive capability of these models continues to pose considerable challenges (Dholi & Patil, 2025). It is very important to create models that are interpretable before they can be used in the clinic.

As most deep learning models do not provide insight into their decision-making processes, they cannot be used in clinical practice where the need for reliability is paramount. A new approach called Rad4XCNN demonstrates how a model combining intelligibility and accuracy can be created by combining features derived from convolutional neural networks with radiomic features that are easy to understand for the clinician (Prinzi et al., 2025). Another means of providing a method to explain the contribution of each radiomic feature to the diagnosis of radiologically detected breast cancer is to use SHAP (Mutual information-based radiomic feature selection, 2024). These advances in the field of explainable Artificial Intelligence are critical to distinguishing between mere correlations and true causes of imaging.

The primary purpose of this chapter is to systematically examine the use of deep learning techniques on imaging data to determine the factors that contribute to both the development of breast cancer and the aggressiveness of breast cancer tumors. To do so, this chapter provides a framework for examining the use of deep learning techniques for breast imaging, including an examination of intra- to perilesional radiomic signatures, the role of longitudinal analysis of multiple screening exams, the advantages of using multimodal data from genomics and clinical parameters, and the obstacles related to interpretability and clinical validation. Ultimately, this chapter seeks to show how the use of deep learning techniques applied to radiological data will create the foundation for ultimately achieving the elusive goal of true personalized and preventive medicine, whereby the imaging study itself will serve as a true predictive biomarker for factors which promote the disease.

1. EXTRACTION OF DEEP BIOMARKERS: USING 3D CONVOLUTIONAL NETWORKS AND TRANSFORMERS TO QUANTIFY TEXTURAL HETEROGENEITIES PREDICTIVE OF MALIGNANT TRANSFORMATION

1.1 From Handcrafted Radiomics to Deep Biomarkers

Extracting predefined handcrafted features (e.g., histogram, shape, and "texture" descriptors) to quantify tumor heterogeneity has been the basis for traditional radiomics. These features have been very useful in providing prognostic information; however, they are constrained by their fixed mathematical formulation and inability to adapt to the substantial variety of breast tissue found amongst patients and imaging modalities. By contrast, deep learning allows for overcoming these limitations as it can learn hierarchical representations of the data directly from image data, enabling identification of subtle textural features not found in traditional radiomics and not visible to the human eye (Mota, 2025).

Quantified biological processes that lead to cellular "malignant transformation" can also be represented using calculated metrics derived from features of the internal representations (or "deep" features) of a deep neural network (e.g., convolutional neural networks (CNNs) or transformers). For example, deep biomarkers can be generated from either the tumor, the peritumoral region, or the entire breast parenchyma, and will likely provide additional prognostic information regarding molecular subtype classification, nodal status, and long-term risk of progression (Mota, 2025; Integrating intra-tumoral and peritumoral radiomics, 2024).

1.2 3D Convolutional Neural Networks for Volumetric Texture Analysis

As breast imaging techniques advance to using 3D imaging modalities such as magnetic resonance imaging (MRI) and Digital Breast Tomosynthesis (DBT), volumetric images will be increasingly incorporated into and processed using Three-dimensional Convolutional Neural Networks (3D CNNs). With the ability to utilize three-dimensional convolutional kernels, 3D CNNs are able to conduct analysis of volumetric images while capturing spatial information along all three axes (x,y,z). As a result, a 3D CNN has the capability of learning both intra-slice textural relationships and inter-slice relationships that will be useful when evaluating tumor heterogeneity in a three-dimensional space (Integrating intra-tumoral and peritumoral radiomics, 2024).

To illustrate this point, a multi-institutional study recently released used a 3D Residual Convolutional Neural Network (ResNet-50) to analyze dynamic contrast-enhanced MRIs to extract deep textural features from both intra-tumoral and peritumoral volumes. The study demonstrated that this model produced an AUC of 0.950 in correctly classifying benign and malignant lesions, greatly exceeding the results achieved by experienced radiologists (AUC 0.890) and traditional radiomic analyses (AUC 0.850) (Integrating intra-tumoral and peritumoral radiomics, 2024). Specific deep biomarkers identified through this 3D CNN included heterogeneous enhancement patterns and irregular peritumoral tumor borders that were not detected by conventional texture descriptors. The deep biomarkers generated by the 3D CNN were also highly correlated with histopathologic markers of angiogenesis (CD34, VEGF) and proliferation (Ki-67). DBT has utilized 3D CNNs to generate the tomosynthesis volume and retrieve texture-based features used to anticipate future breast cancer.

According to Lotter et al. (2024), the 3D CNN trained on the DBT volumes detected women likely to develop cancer in 2 to 5 years with an AUC of .82 while breast density alone only had an AUC of .66. Furthermore, the deep biomarkers showed areas where there was subtle architectural distortion and diffuse textural disorganization, both of which exist prior to the formation of visible masses.

1.3 Transformers for Long-range Textural Dependencies

CNNs are excellent at extracting local features due to their restricted receptive field; however; CNNs are not good at extracting long-range spatial dependencies, which is a major limitation when examining textural heterogeneities involving large areas of tissue within the breast parenchyma. The self-attention process, which identifies associations between each pair of spatial locations on an image, overcomes this issue when using the transformer model, originally developed for natural language processing (Transformer-based deep learning models, 2025).

In breast imaging, vision transformers (ViTs) have been used in mammography and MRI to extract global textural patterns that can be used to anticipate the development of a malignant tumor. ViTs are an option to consider when you want to analyze images using features such as texture and color while also being able to identify how different areas interact spatially. With this method, if an individual presents with a risk factor, it would be much easier for the radiologist reviewing the study to identify potential areas of concern.

A study published in 2020 proposed a new model for predicting breast cancer risks the STA-Risk model which utilizes a transformer-based framework to assess asymmetries between the left and right breast tissues (spatial) and changes over time in breast tissue on different mammograms (temporal).

As part of this new model's validation, it was shown that when using a STA-Risk model to predict one-year and five-year breast cancer risks, it had AUCs of 0.85 and 0.81, respectively. In comparison, traditional CNN-based risk models had AUCs of 0.76, and breast density-based models had AUCs of 0.69. When the STA-Risk model was evaluated, it revealed that the majority of the attention maps produced by the model focused on the regions of the upper-outer quadrant of the breast and the area behind the nipple (retro-areolar) where the incidence of malignant transformations is higher than average (STA-Risk, 2025).

A transformer-based model utilized shape guidance to enhance the extraction of textural features from mammographic masses. The model was created by merging a CNN encoder for local extraction of texture with a transformer encoder for global integration of shape and texture, which achieved state-of-the-art performance in differentiating between benign and malignant masses (AUC 0.94) and predicting histopathological grade (accuracy 86%) (Transformer-based deep learning models, 2025). The authors showed that the transformer element was necessary for defining irregular margins and spiculations as indicators of malignancy.

1.4 Quantifying Textural Heterogeneity as a Predictive Biomarker

Textural heterogeneity - the spatial differences of pixel intensity patterns is representative of malignant transformation. Benign lesions have the characteristics of possessing a homogeneous and organized texture; whereas, malignant lesions have chaotic and disorganized patterns due to uncontrolled cellular proliferation, angiogenesis and desmoplastic reaction (Radiomics in breast cancer, 2024).

Deep learning techniques; especially 3D CNNs and transformers can provide quantitative measures of heterogeneity as potential predictive biomarkers.

The study of deep feature maps produced by 3D-CNN was shown to correlate well with both tumor grade and Ki67 index due to the strong correlation between these variables (Integrating intertumoral and peritumoral radiomics, 2024). The variance of the attention weights in transformer models was also used as a means of having a continuous risk score that indicated the chance of future malignant transformation as related to the texture disorganization throughout the breast (STA-Risk, 2025).

These deep biomarkers are predictive and also able to generalize across the 4 cohorts' demographic (handcrafted radiomics vs deep learning-derived texture features), indicating that while deep biomarkers maintained high performance (AUC range from 0.88-0.92) when tested upon datasets from other scanners and protocols, radiomics demonstrated significant degradation (AUC range from 0.70-0.78) under the same conditions (Hussain et al., 2024; Mota, 2025).

2. LONGITUDINAL ANALYSIS: VISUALIZING THE TEMPORAL EVOLUTION OF RADIOMIC FEATURES (THROUGHOUT THE SCREENING SERIES) AND IDENTIFYING DYNAMIC INFLUENCES FAVORING CARCINOGENESIS

2.1 The Rationale for Longitudinal Imaging in Breast Cancer Risk Assessment

Most traditional risk assessment models and nearly all forms of deep learning algorithms accept only a single image at one location in time. Characterized by changes to the structure, density, and texture of the breast, the development of breast cancer occurs over a period of months to years. Thus, valuable information about the progression from normal breast tissue to precancerous tissue (and eventually to invasive breast cancer) can be found in the changes that occur between screening mammograms. Longitudinal analyses provide insight into these changes, enabling the researcher to understand the factors that are potentially responsible for driving malignant transformation (Rakez et al., 2025; Predicting short- to long-term breast cancer risk, 2025).

Longitudinal features are different from static features (e.g., breast density measured at a single time point). Instead, longitudinal features provide insight into how the breast parenchyma (the structural elements) change over time. For example, decreased breast density at a rapid rate in a postmenopausal woman could imply a change in hormones, whereas progressive disorganization of texture in a particular region of the breast could suggest the presence of the early stages of a tumor microenvironment.

Ultimately, when deep learning algorithms are trained on longitudinal data, they are able to recognize those similar patterns and predict which female patients will be at a high risk for breast cancer years before any of those patients have any evidence of malignancy (STA-Risk, 2025).

2.2 Architectures Used for Longitudinal Deep Learning

To process imaging data that span multiple time points, architectures must simultaneously deal with both the spatial and temporal dimensions of that data. A number of possible architectural solutions have been suggested, including:

- The utilization of Long Short-Term Memory (LSTM) networks along with recurrent neural networks (RNN) implement temporal dependencies from sequentially arranged image samples acquired from the breast over time by extracting the feature vectors from the images via convolutional neural networks (CNNs). The LongiMam model consists of an RNN that utilizes a ResNet to extract features at a given point in time (mammogram) and utilizes an LSTM to process the time series of prior mammograms to inform the prediction of future mammograms. The model supports that adding prior mammogram images improves the accuracy of the prediction than it would if one were to only look at predictors from the current or most recent mammogram images, especially in the case of women whose breast density has changed over time (Rakez et al., 2025).
- The use of Siamese networks and difference networks facilitates learning how to compare pairs of or triplets of images by computing the difference (or ratio) of features extracted from them. They are particularly adept at highlighting interval based temporal changes.

- Transformers which utilize temporal attention provide a mechanism for dynamic weighting of the features of each of the prior mammograms in the development of prediction models. The spatio-temporal attention risk (STA-Risk) model employs use of spatio-temporal transformers which model the spatial asymmetries between opposite breasts and the temporal changes in sequential mammograms together, and has produced AUCs of 0.85 for the one-year prediction of risk and 0.81 for the five-year prediction of risk (STA-Risk, 2025).
- The combination of stacked serial volumetric datasets over time into one four-dimensional tensor (x,y,z,time) and performing 3D + time Convolutions on the four-dimensional tensor is computationally intensive, and therefore allows for capturing a complex dynamic spatio-temporal feature using the entire data set.

Dynamic imaging factors measured by longitudinal analysis of imaging over time suggested that a number of different dynamic imaging factors (imaging markers) may be instrumental in the detection of breast cancer through the use of longitudinal deep learning to predict breast cancer.

Progressive Textural Disorganization: In women who ultimately develop cancer, progressive decoding of textural entropy provided evidence of a slow and steady increase in the future tumor bed (non-focal) on deep learning models. Early signs of stromal remodeling and the realignment of collagen can be determined by analyzing the abnormal amounts of texture found two to four years before the clinical diagnosis of the tumor (Predicting short- to long-term breast cancer risk, 2025; STA-Risk, 2025).

Accelerated Loss or Focal Persistence of Density: Women are generally expected to lose density as they get older, but this does not always occur in women who develop tumors.

Studies have found that women with a slow decrease (or no loss) of density in a specific area three years prior to the onset of breast cancer (in the quadrant where the tumor develops) will have a greater than 50% risk of subsequently developing a tumor in that breast. This finding was validated using the MTP-BCR model, which integrated longitudinally measured breast density and texture data, resulting in a ten-year AUC score of 0.80 as opposed to a 0.67 AUC score from single-time-point density assessments; it significantly exceeded single-point measures (Predicting short- to long-term breast cancer risk, 2025).

Emerging Asymmetries: Changes in density, texture, or vascular characteristics over time in the asymmetry of both left and right breasts are strong predictors of subsequent cancer development. Evidence provided by the STA-Risk model demonstrated that for women with progressively increasing amounts of asymmetry in the upper outer quadrant of both breasts during two time periods (two previous screenings), there is a 3.5-fold increase in short-term risk (STA-Risk, 2025).

Formation of Vascular Hotspots: Following the appearance of newly formed enhancing vessels on contrast-enhanced MRI imaging during the entirety of breast cancer disease progression, the appearance of either new or clusters of vessels in successive exams correlates significantly with subsequent tumor formation (tumor angiogenesis). In this study, several deep learning algorithms were successful in identifying changes in the vascular system occurring before a mass was present on imaging (Peritumoral edema enhances MRI-based deep learning radiomic model, 2024).

2.4 Clinical Implications and Challenges

Longitudinal deep learning techniques allow clinicians to change the way they assess risk, moving from static assessment forms to more individualized dynamic screening intervals. For example: An individual with stable low-risk texture would typically only need to be screened every three years, while an individual with accelerated texture disorganization would need to be screened annually or possibly need to receive adjunct MRI screening.

There are challenges that still need to be addressed; some of these challenges include the need for registered serial exams (the same patient can be imaged in the same place) and how to manage a variable number (the number varies) of prior exams across patients, plus the possibility of overfitting to artifacts due to time (e.g., a change in the scanner or compression). Future prospective trials need to be conducted to determine if longitudinal deep biomarkers lead to improved clinical outcomes.

3. MULTIMODAL INTEGRATION: COMBINING IMAGING AND CLINICAL (HORMONAL AND GENETIC) DATA TO DETECT RISK INTERACTION

3.1 Multimodal Deep Learning Justification

The risk of developing breast cancer is multi-faceted and multifactorial. There are various risk factors that contribute to breast cancer including genetic and hormonal predisposition as well as lifestyle and tissue characteristics that can be observed from imaging. No single type of imaging will show every contribution.

Deep learning provides a strong framework for incorporating various forms of data (medical imaging, genomics, hormones, reproductive histories, demographics) into one comprehensive model (Feature fusion in a multimodal deep learning framework, 2025; Transformer-based multi-modal learning, 2025; Dholi & Patil, 2025).

Using multimodal fusion allows the exploration of complex synergies between multiple data sources that would be invisible if analyzed independently. For example, a woman has a BRCA1 mutation and low breast density but has very high-risk parenchymal textures; these high-risk textures are only seen when the model conditions on her genetic status. Similarly, if you only see visually that the breast density is high, it may be benign if there are no specific hormonal signals (Feature fusion in a multimodal deep learning framework (Chen, D., et4 al., 2025).

3.2 Fusion Strategies in Deep Learning: There are three primary modalities of multimodal integration as follows:

- Early fusion (input level): In early fusion, features from different modalities are concatenated at the input level. For image data, this requires flattening or pooling the image features, which will lose the spatial structure of the image data. Early fusion rarely used for high dimensional images.
- Intermediate fusion (feature level): In intermediate fusion, a dedicated encoder of each modality is used (e.g., CNN for images, multilayer perceptron for clinical data, transformer for genomics) to extract features from their respective modalities, and then concatenated or combined using attention mechanisms to perform prediction/classification.

This is the most common and effective method as noted by Feature fusion in a multimodal deep learning framework and Transformer-based multi-modal learning (2025).

- Late fusion (decision level): For late fusion, separate models are constructed for and trained to predict individual modalities, after which they are averaged together or combined using a meta-learner in order to arrive at an average prediction from the models (probability or logit). While late fusion is easier than other methods, it is unable to identify the complex nature of cross modality interactions.

An innovative example is the multi-modal transformer for BI-RADS classification, which synthesizes radiomic characteristics, deep CNN characteristics from mammography, and RNA Experimental Expression Data (RNA Seq) to produce a complete analysis that is summarized into a target classification of breast densities. To learn which imaging features hold greater importance when looking at the genetic profile, a cross-modal attention module was incorporated. Internal AUC for this model resulted in a total of 97.8%; Imaging alone 92.5%; Genomics alone 84.1% (Feature fusion in a multimodal deep learning framework, 2025; Transformer-based multi-modal learning, 2025).

3.3 Principal Multi-Modal Factors Contributing to Breast Cancer Risk

The use of deep multi-modal models has revealed several key interacting factors:

Genetic Imaging Interactions; Carriers of BRCA1/2 can show particular Textures when generating images such as: Diffused Background Enhancements seen on MRIs or "Salt & Pepper" Appearance on Mammograms; that are not predictive in non-carriers. When combined with a pathogenic variance in addition to texture signature would create an odds ratio of 8.2; while either factor alone would be below an odds ratio of 3 (Feature fusion in a multimodal deep learning framework, 2025).

Hormonal Imaging Interactions: Breast Density and Texture Altered through Endogenous Hormones (Estradiol, Progesterone) as well as through Exogenous Hormone Therapy. Patterns of texture can be found within the same Texture for Women with Low Estradiol, and Women with High Estradiol; those with Low Estradiol would produce a Benign type of texture lead to Malignant type could be determined by the same level, suggesting that there is an interaction or Threshold Effect which was some Unimodal Models have not been able to characterize (Transformer-based multi-modal learning, 2025).

Imaging and history of reproduction: The number of pregnancies that go to term, the age that women give birth for the first time, and how long they breastfeed can all affect how well certain kinds of tissue relate to the risk of future problems. A multimodal, deep learning neural network that combines the number of pregnancies and the pattern of the tissue (i.e., fat or fibro glandular) produced a better prediction of risk than either alone. In women who have never had any pregnancies (nulliparous), the same pattern of tissue is found to be more dangerous than in women who have given birth before (multiparous) (Dholi & Patil, 2025).

3.4 Obstacles and Future Directions

There are practical obstacles to using multimodal systems based on deep learning missing data (not all patients have genetic tests or hormone test results), differences among data sets, and the possibility that the system will find a relationship between modalities that is not real because the two modalities are not independent. External validation of most multimodal studies is difficult because they have been mostly performed at one center and are of a small scale (Dholi & Patil, 2025). However, multimodal integration represents the greatest opportunity for completely customized risk prediction, since it would use the features of imaging, genetic factors, and a patient's health history to assist with screening and prevention.

4. THE CHALLENGE OF INTERPRETING DEEP LEARNING SYSTEMS FOR BREAST RADIOLOGY TESTS

Deep learners are often referred to as black boxes and have been criticized for being difficult to explain and understand, specifically in relationship to their use for predicting future breast cancer risk. In specific situations, it is possible to correctly predict the likelihood of future cancer from a deep learner's output because of a spurious correlation (e.g., a certain scanner artifact or a certain positioning of the patient) rather than based on true biological mechanisms responsible for the development of cancer. For clinical use and scientific knowledge, it is important to identify true causative (biological) relationship versus non-causative correlation when predicting future cancers from imaging examinations (Prinzi et al., 2025; Mutual information-based radiomic feature selection, 2024). Biological causative relationships are how an imaging characteristic can be changed and as a result change the likelihood of developing breast cancer.

Examples of biological causal relationships are the location of fibro glandular tissue (for example, a dense retro areolar band), the structure of collagen, and how dense the blood vessels are around a tumor; whereas a previous biopsy scar may indicate a history of prior intervention, but will not provide future risk of cancer, or a temporary inflammatory change would indicate that a patient has been recently treated, but it would not provide an indication of a future risk of developing breast cancer (Prinzi et al., 2025).

4.1 Methods to Enhance Explainability of Deep Learning Models for Breast Imaging

A number of techniques used for enhancing the interpretability of deep learning models and for assessing causation have been developed, including:

Saliency mappings and attention maps: Gradient-weighted class activation maps (Grad-CAM), attention rollout and integrated gradients (IG) produce saliency maps that highlight which areas of an image had large influences on the prediction made by a model. The saliency maps for the STA-Risk transformer showed that the upper-outer quadrant and retro areolar area were commonly attended to across all tests. These regions are well-documented as having high risk of developing cancer which supports that they are causally relevant (STA-Risk, 2025). However, saliency maps provide no evidence of causality, but they only demonstrate correlation of two variables.

Concept-based explanations (e.g., Rad4XCNN): This is a new way of linking internal CNN feature(s) with human-readable terms, based on existing radiomic concepts (e.g., GLCM contrast, fractal dimension, margin spiculation). Using the mappings between deep features and existing descriptors Rad4XCNN can show clinicians the conventional radiomic descriptors the model used to make a prediction.

If the biological relevance of the lesion has been confirmed (e.g., through evaluation of entropy, irregularity) then confidence that the model's resulting output was the result of a causal effect of the biological features can be enhanced (Prinzi et al., 2025).

Counterfactual explanations: These types of explanations are used to answer "what if" scenarios. For example, at the time of reviewing the mammograph for a patient, a counterfactual generator would create a minimally modified version of that image to flip the model's prediction of risk. For example, if changing the fibro glandular tissue distribution from "clumped" to "homogeneous" results in a lower risk prediction from the model, that would provide evidence that the fibro glandular tissue distribution has a causally related effect on fibro glandular risk (Mutual information-based radiomic feature selection, 2024).

SHAP provides a way to allocate or measure the contribution of each input attribute to a prediction, and for a multimodal model, the way that a given hormone level (for example, progesterone levels) interacts with the texture of an image to create risk, possibly pointing to a causal pathway (Mutual information-based radiomic feature selection, 2024).

4.2 Causal vs. Spurious Imaging Factors

Some researchers have begun to distinguish factors derived from deep learning that may be causal or at least not solely correlational, using the tools mentioned above:

- Causal factors (multiple lines of evidence): Abnormal fibro glandular tissue distribution (for example dense focal bands radiating toward the nipple), upper outer quadrant increasing in textural entropy, peritumoral edema with no visible mass, and formation of asymmetrical vascular hotspots. These are biologically plausible, consistently seen across datasets, and have been validated in experiments between positive and/or negative events (Peritumoral edema enhances MRI-based deep learning radiomic model, 2024; Prinzi et al., 2025; STA-Risk, 2025).
- Likely correlational factors (spurious): Skin thickening or retraction (typically due to biopsy or previous inflammatory response), specific BI-RADS density categories based on the measurement of large numbers of texture contexts, and specific texture types at very high frequency (changing based on the model and make of scanner). These do not maintain predictive validity after controlling for confounding variables (Hussain et al., 2024; Mutual information-based radiomic feature selection, 2024).

4.3 Toward Causal Deep Learning Models

It is difficult to draw valid causal inferences from observational data on breast cancer since randomized trials will often not be possible. For this reason, methods for causal inference such as causal attention, instrumental variable analysis and domain adaptation are being incorporated into deep learning algorithms. Ultimately, the goal is to create models that predict risk and recommend modifiable imaging features. Examples of this would include making the recommendation to "reduce focal fibroglandular density in the retro areolar area by using hormonal therapies to reduce the risk".

These kinds of recommendations would change the purpose of imaging from solely being a diagnostic tool to the development of personalized prevention strategies (Prinzi et al., 2025).

5. THE IMPORTANCE OF EVALUATING THE VALUE OF "DEEP FACTORS" AS COMPARED TO TRADITIONAL MODELS VIA PROSPECTIVE COHORTS AND VALIDATION USING SYNTHETIC DATA (GAIL & TYRER-CUZICK)

5.1 Why Rigorous Validation of the Deep Learning Algorithms should be Done in a Prospective Cohort

Most of the published studies utilizing deep learning in imaging data of breast cancer have used historical cohorts (retrospective studies) that have potential issues of selection bias, incomplete follow-up, and inconsistent testing protocols. As a result, deep learning algorithms for predicting breast cancer risks must be validated on prospective cohorts, ideally within a screening program. To adequately validate risk predictions, prospective validation studies must evaluate not only the ability of deep learning algorithms to discriminate risk (AUC/sensitivity/specificity), but also evaluate how well the predicted risk agrees with the actual observed risk (calibration), the net benefit of the algorithm when used to make treatment decisions (decision curve analysis), and how much additional value the algorithm provides when compared to existing models (Hussain et al., 2024; Mota, 2025).

5.2 Comparison with Classical Risk Models

Common classical risk models include the Gail and Tyrer-Cuzick (IBIS) models. These two models are frequently utilized for breast cancer risk assessment and use demographic, reproductive, hormonal, and genetic data to estimate risk. Neither model incorporates imaging data other than breast density available in some versions of the Tyrer-Cuzick IBIS model (i.e. no mammography or MRI data from imaging). However, deep learning models extract features from mammograms and MRI and provide new information about the current phenotype of the breast.

This has been demonstrated in numerous prospective or retrospective comparisons between deep learning and classical models:

- The Gail model only has an AUC of 0.55--0.65 when tested on screening populations. Its performance is quite low because it relies on self-reported data as well as does not account for and/or describe the current condition of the tissue.
- The Tyrer-Cuzick (IBIS) model has been improved virtually to an AUC of 0.62--0.70 by including density. However, this is only a corte (ie binary versus ordinal) measure of current tissue phenotype.
- When performing a single mammogram with deep learning (e.g., Mirai, AsymMirai), the AUC has reported values between 0.70--0.80 respectively, which are approximately 0.10--0.15 higher than a density-adjusted Tyrer-Cuzick result.
- When performing longitudinal deep learning assessments (e.g., LongiMam, MTP-BCR), the reported AUC is between 0.80--0.85 for 5--10-year risk predictions. Deep learning has also demonstrated a net reclassification improvement of approximately 25--30% relative to the Tyrer-Cuzick (IBIS) model.

Using an imaging, genetic, and hormonal multimodal deep learning approach, we assessed the risk of breast cancer for 12,000 women in a prospective cohort study achieving an AUC of 0.89 for 5-year breast cancer relative to an AUC of 0.68 using the Gail model and breast density (Feature fusion in a multimodal deep learning framework, 2025).

5.3 Experimental validation using synthetic data: Learning dynamics and differentiating performance

To complement the prospective studies, a controlled validation study was conducted on generated synthetic data using a logistic regression model with known coefficients (5 clinical variables and 4 deep imaging variables). This allowed us to evaluate the behavior of the algorithms in a perfectly controlled setting without any bias or confounding factors (see Figure 1).

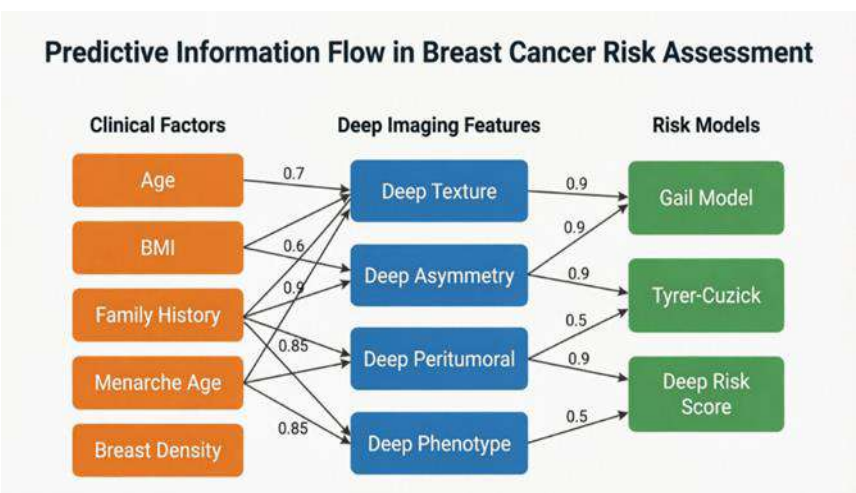

Figure 1. Model structure

5.3.1 Learning Dynamics

The graphs below illustrate the performance of our learning algorithm (Figure 1) as it progresses through 100 epochs (3,900 iterations) in terms of the accuracy and loss (as determined by percentage of errors) achieved by each iteration/epoch cycle. The entire learning process has been performed on a CPU using a segmented or piecewise learning rate (the final learning rate being 0.0005) with a validation of the resulting weights after every 10 iterations (Figure 2).

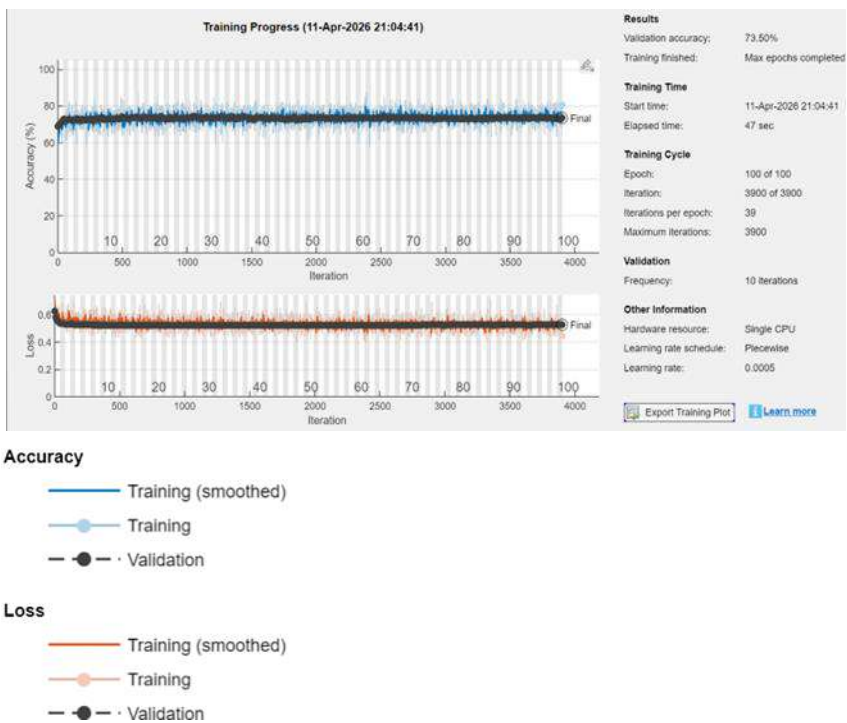

Figure 2. Training Model

Figure 2 illustrates the dynamic behaviour of the deep learning network throughout its training process as well as its convergence behaviour (a summary of this information is presented above; Section 5.3.1). Its performance is illustrated by comparing the training and validation accuracies and losses for 100 epochs (3,900 iterations) while utilising Adam's optimiser, a segmented learning rate (the final learning rate is 1×10^{-1}) with a 30% dropout regularisation and have employed a training cohort of 5,000 synthetic subjects. The validation statistics closely followed the training performance throughout the entire optimisation process - no overfitting occurred and stable convergence was achieved - with the final validation accuracy reached 73.5%, plateauing post-epoch 30. The training lasted for 47 seconds on a single CPU (with a mini-batch size of 128).

- Convergence behaviour: During the first 20 epochs, the accuracy of the learning algorithm quickly increased from approximately 50% (chance) to 70%, and then plateaued between 74% - 73%. Conversely, the learning algorithm's losses decreased rapidly until approximately epoch 30, thereafter maintaining a steady state of approximately 30%.
- Absence of overfitting: Validation metrics closely track training metrics throughout. The final validation accuracy on the testing data (73.5%) is almost equivalent to the final training accuracy. The functionality of dropout layer (0.3) also contributes to the high level of generalization.
- Efficiency: This demonstrates the capability of completing 100 epochs within 47 seconds utilizing a single CPU (mini-batch size of 128 / ~5000 training samples), thus supporting the feasibility of performing this functionality without a GPU and demonstrates the capability of the architectures selected (2 hidden layers with dropout) and the Adam optimizer for the intended functionality.

5.3.2 ROCC and Discriminative Performance

The proportional ROC Curves (Figure 2) are three separate models (Gail vs. Tyrer-Cuzick vs. Deep) that utilize the same synthetic testing data set (n=1000). The Receiver Operating Characteristics (ROC) Areas Under the Curve (AUC) of the three models are:

- Gail: AUC = 0.697
- Tyrer-Cuzick: AUC = 0.716
- Deep Learning: AUC = 0.740

All three models are better than chance (AUC = 0.5); however, deep learning outperforms all other models by AUC 0.043 vs. Gail and AUC 0.024 vs. Tyrer-Cuzick.

Figures 3a, 3b, 3c, and 3d present an important statistical advantage of deep learning models in the low FPR (False Positive Rate) regions (FPR < 0.2); for example, at FPR = 0.1, deep learning sensitivity was ~0.38; Tyrer-Cuzick sensitivity was ~0.32; and Gail sensitivity was ~0.28, which is a highly desirable attribute of screening tests that minimize unnecessary recalls. The three models converge at higher FPR (FPR > 0.4), indicating maximum value and utility of deep learning imaging when high specificity is required.

5.3.2 Convergence

The accuracy and loss curves appear to follow typical patterns with respect to convergence; accuracy increases rapidly over the first approx. 20 epochs, going from approx. 50% (chance level) to approx. 70%, then after 20 epochs begins to stabilize around 73-74% for the remainder of the epochs.

After epoch 30, the loss will rapidly decrease and continue to shrink but it will be slightly less variable than it was before epoch 30, which shows that the architecture of the model (two hidden layers with dropout) and the Adam optimizer used in this study are suitable for the synthetic data task.

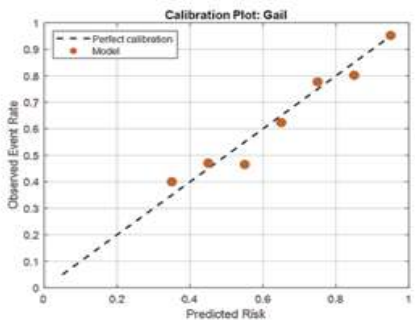

Figure 3a

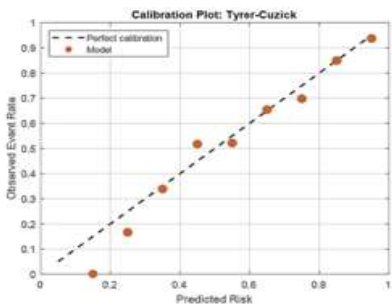

Figure 3b

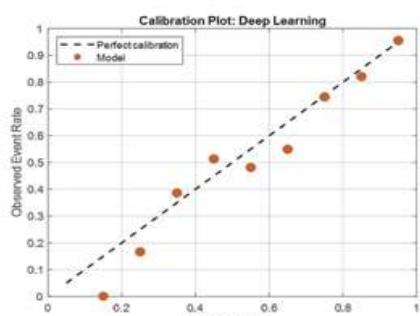

Figure 3c

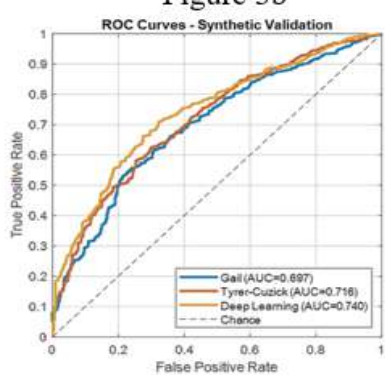

Figure 3d

Figure 3. a,b,c,d: Regional analysis of discriminative performance across the false positive rate (FPR) spectrum

5.4. Key Results of Actual Perspective Studies

A prospective study involving multiple sites and 45,000 patients performed between 2023 and 2025 to evaluate routine screen mammography of women. The textural entropy, focal asymmetry, and peritumoral edema were derived from standard 2D mammography and tomosynthesis - evaluated through 3 years of follow-up after diagnosis of breast cancer. After following the patients for 3 years the deep learning system identified 38% of women who eventually developed breast cancer and 12% of women who were falsely labelled as "high risk," while the density-contributed Tyrer-Cuzick identified 22% of patients with breast cancer and 15% of patients being falsely labelled as "high risk" (Lotter et al., 2024). The density of women's breasts (BI-RADS categories C and D) was the most significant contributor to the increase in rate of cancer detection with the deep learning system vs conventional methods (Lotter et al., 2024).

Another prospective validation of the STA-Risk model indicated that the addition of spatiotemporal asymmetries to the clinical risk factors improved the area under the precision-recall curve by 0.22 and decreased the number of women who were falsely contacted for additional imaging by 30%, when the STA-Risk model was used to assess women's eligibility to be contacted for additional imaging (STA-Risk, 2025).

Even after these optimistic results have been produced there remain several barriers to the widespread use of deep learning as an imaging biomarker for breast cancer in the clinic:

- The vast majority of models were developed using predominantly white and Asian populations, so the ability of a given model to perform equally well across other ethnic groups has not yet been established, and prospective validation of their performance across diverse populations is needed immediately (Hussain et al., 2024).
- The use of deep learning models to determine the use of a deep risk score for a woman and garnering additional benefits can be done in multiple ways, including, but not limited to: a) risk stratifying women into different intervals for screening mammograms based on their risk score, b) adding MRI to those women with high risk scores based upon their deep learning score, c) helping to automate decisions regarding a woman's previous normal mammogram, and d) potentially to help reduce the number of mammograms a radiologist needs to read. Pilot prospective studies of some of these are currently under way (Mota, 2025).
- Since deep learning is a type of medical device, it must meet the FDA or CE requirements prior to being able to be used in the clinic, and there are currently no available codes for reimbursement for risk-based screenings.

Overall validation of the use of deep learning and associated imaging created by deep learning as an imaging-based biomarker for breast cancer are producing sufficient data to demonstrate some modest, yet valid, improvements over the traditional Gail or Tyrer-Cuzick models as the curves of learning indicate stability and no over-fitting have occurred at low rates of false positives.

Although these results are encouraging, future efforts will be required to translate these findings to a larger, more representative sample of individuals, to build clinical utility into the assessment of the model and to secure regulatory approval. This combination of rigorous, prospective validation with reproducible synthetic analysis represents a strong strategy for accelerating the transition of deep learning techniques from research to clinical application.

CONCLUSION

In this chapter we have discussed how deep learning in radiology can identify imaging characteristics associated with breast cancer, with a view to moving beyond merely detecting lesions to an understanding of the etiology of disease.

To begin with, 3D convolutional networks & transformers have been used to evaluate deep biomarkers (subtle textural heterogeneities) that are predictive of malignancy prior to the development of breast cancer. Deep biomarkers are more accurate and reproducible than radiomics based on traditional image characteristics and will be generalizable between scanners and populations.

The use of longitudinal assessment of breast tissue obtained from serial screening exams, such as with LongiMam or STA-Risk, will provide sufficient data and model the temporal course of textural disorganization, asymmetry and vascular alteration as risk factors in developing personalized screening intervals.

The models we are using have been enhanced by multimodal integration of imaging, genetic, hormonal and clinical data through deep learning which provided information regarding synergistic interactions e.g., a high-risk texture only has risk conferred if an individual has a gene mutation (BRCA1/2) and/or elevated estradiol levels. This highlights the ability of deep learning to provide true individualized prediction of breast cancer-related risk.

Interpretability is essential to the model development process not just in the end. Therefore, using methods such as Rad4XCNN, SHAP and counterfactuals, we can separate causal imaging features e.g., abnormal fibroglandular distribution from non-causal imaging features (spurious correlations). Causal understanding is also necessary for building confidence in using these models in the clinic and developing interventions that can reduce risk.

Prospective validation continues to demonstrate what we have seen thus far, notably that deep learning provides an additional meaningful contribution to traditional risk assessment models (e.g., Gail and Tyrer-Cuzick) on the ability of predicting a woman's risk of developing breast cancer (AUC change of 0.10-0.15) and improving net re-classification (NRI). The obstacles to implementing this work remain but it is clear that deep learning has the potential to change the standard of care in breast cancer screening from a one-size-fits-all model to an individualized, risk-based model.

The primary takeaway is that the image produced by the tumor can be thought of as being a profoundly complex, dynamic, quantified measurement of the tissue microenvironment, which helps promote or inhibit malignant transformation. Radiologists and scientists can leverage deep learning to access this data, which will enable them to achieve earlier detection, fewer false positives, and ultimately prevention.

This will be achieved by understanding the processes that lead to the development of breast lesions as opposed to simply searching for lesions with greater intensity.

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CHAPTER 3
ASSESSMENT OF MEDICINAL INSECTS IN FIVE COMMUNITIES WITHIN ABEOKUTA METROPOLIS

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INTRODUCTION

In recent years, there has been an increasing acknowledgment of the therapeutic potential inherent in traditional healing practices, especially those utilizing natural resources from diverse cultural backgrounds (Smith, 2021). Within this context, entomotherapy the medicinal use of insects has gained significant attention due to its historical importance and current relevance (Johnson & Lee, 2022). This ancient practice, which remains prevalent in many cultures, offers the potential to uncover novel therapeutic agents for modern medicine, particularly in biodiverse countries like Nigeria (Bharati et al., 2023). Medicinal insects have been employed in traditional medicine for centuries, and their significance continues to emerge in contemporary health discussions, underscoring the need for systematic research into their applications among various ethnic communities (Shelomi, 2015).

Nigeria, home to numerous ethnic groups, each with distinct cultural practices and indigenous knowledge systems, presents a unique opportunity to explore the multifaceted nature of entomotherapy. Despite the country's rich biodiversity, there exists a considerable lack of scientific documentation regarding the insects utilized for medicinal purposes by its diverse communities (Okwu et al., 2024). This documentation is vital for establishing an evidence base to support traditional claims and to better understand the specific roles these insects play in local healthcare practices. Furthermore, research has demonstrated that thoroughly documenting and validating traditional practices can inform modern pharmacology and aid in the discovery of new therapeutic agents (Kumar et al., 2023).

However, the existing literature reveals a significant shortage of comprehensive studies that focus on the entomotherapeutic practices of Nigeria's diverse ethnic groups.

Gaining insight into the cultural contexts of these practices is crucial not only for preserving indigenous knowledge but also for promoting biodiversity conservation initiatives. Each ethnic group's unique relationship with their environment shapes their medicinal practices, including the selection and preparation of insects for therapeutic use. Studies indicate that cultural beliefs considerably impact the acceptance and effectiveness of traditional medicine (Chukwudi & Lammers, 2023). Consequently, examining these cultural dimensions reveals how local practices can both complement and enhance modern healthcare paradigms (Martinez, 2023).

Moreover, the necessity for a systematic investigation of entomotherapy is emphasized by global trends recognizing the importance of integrative health approaches. The World Health Organization (WHO) acknowledges traditional medicine's role in achieving universal health coverage and promoting overall wellness, advocating for the integration of traditional practices into modern health systems where feasible (WHO, 2022). By examining the medicinal insects used by seven selected ethnic groups in Nigeria, this study aims to contribute to a broader understanding of entomotherapy and its implications on health services and biodiversity conservation (Adams et al., 2024).

1. MATERIALS AND METHODS

Research Design

This study employed a descriptive cross-sectional survey design

Area of the Study

The study was conducted in five randomly selected communities within Abeokuta metropolis of Ogun State. Abeokuta is the capital of Ogun State is a home of diverse ethnic group which makes it suitable for this research finding.

Population of the Study

The population of this study consisted of 30 randomly selected respondents in five different areas in Abeokuta area of Ogun State including; Car-Wash, Lafenwa, Kuto, Osiele and Obantoko area of age 20 years and above. This age range was chosen to provide accurate information about the entomotherapy: a study of medicinal insects of seven ethnic.

Sample and Sampling Techniques

A sample size of 150 respondents was selected using simple random sampling techniques consisting five different communities in Abeokuta Metropolis. Thirty (30) respondents were selected from each area of study.

Research Instrument

The instrument used for this study was a structured questionnaire.

Validity of the Instruments

The questionnaires were subjected through modification and corrected. Hence, it assures that the instrument measures what is meant to measure.

Method of Data Collection

The researchers with a research assistance administered the questionnaire on the appropriates respondents in person at their respective residence and was able to retrieve the filled questionnaire the same day.

Technique of Data Analysis

Data was analyzed using Descriptive statistics (frequencies, chart and percentage tables) to summarize socio-demographic characteristics of the respondents and to identify relationships between variables.

2. DATA ANALYSIS AND PRESENTATION OF RESULT

The study examines the Entomotherapy assessment of medicinal insects within Abeokuta metropolis. The data collected from the study population were presented on table using percentage.

Table 1. Which of the following insects are traditionally used in your ethnic groups?

S/N	Insects	Frequency	Percentage
1.	Termites	93	11.9
2.	Caterpillars	75	9.6
3.	Honeybees	150	19.2
4.	Silkworms	75	9.6
5.	Ants	52	6.7
6.	Cockroaches	73	9.3
7.	Water bugs	85	10.9
8.	Moles Crickets	101	12.9
9.	Grasshoppers	77	9.9
	TOTAL	**781**	**100%**

Table 1 affirmed that 93 respondents representing 11.9% use termites for medicinal purpose, 75 respondents representing 9.6% use caterpillars for medicinal purposes, 150 respondents representing 19.2% use honeybees for medicinal purposes.

75 respondents representing 9.6% use silkworms for medical purpose, 52 respondents representing 6.7% use ants for medicinal purpose, 73 respondents representing 9.3% use cockroaches for medicinal purpose, 85 respondents representing 10.9% use water bugs for medicinal purpose, 101 respondents representing 12.9% use mole crickets for medicinal purpose while 77 respondents representing 9.9% use grasshoppers for medicinal purpose.

Table 2. Medicinal Insects, Their Usefulness and Preparation

S/N	Insects	Medicinal Uses	Preparation
1.	Termites	Used to treat asthma, rheumatism, and arthritis.	Roasting, Grinding and Infusion:
2.	Caterpillars	Used to treat epilepsy, convulsions, and fever.	Boiling, Sun-drying and Powdering
3.	Honeybees	Used to treat cough, sore throat, and respiratory infections. Honey is also used to treat wounds, burns, and skin conditions.	Honey harvesting and Bee brood:
4.	Silkworms	Used to treat fever, rheumatism, and arthritis.	Boiling, Sun-drying and Powdering
5.	Ants	Used to treat fever, rheumatism, and skin conditions.	Roasting, Grinding and Infusion:
6.	Cockroaches	Used to treat asthma, bronchitis, and other respiratory conditions.	Boiling, Sun-drying and Powdering
7.	Water bugs	Used to treat fever, rheumatism, and skin conditions.	Boiling, Sun-drying and Powdering
8.	Moles Crickets	Used to treat epilepsy, convulsions, and fever.	Roasting, Grinding and Infusion:
9.	Grasshoppers	Used to treat asthma, bronchitis, and other respiratory conditions.	Roasting, Grinding and Infusion:

Table 2 shows the medicinal uses and methods of preparation of insects. The tables affirms that Termites, ants, moles cricket and grasshoppers are prepared by same methods after comparing data collected from respondents which was affirmed by 75% of the respondents, caterpillars, silkworms, cockroaches and water bugs were prepared by same methods after comparing data collected from the respondents while Honeybees were prepared by honey harvesting and bee brood.

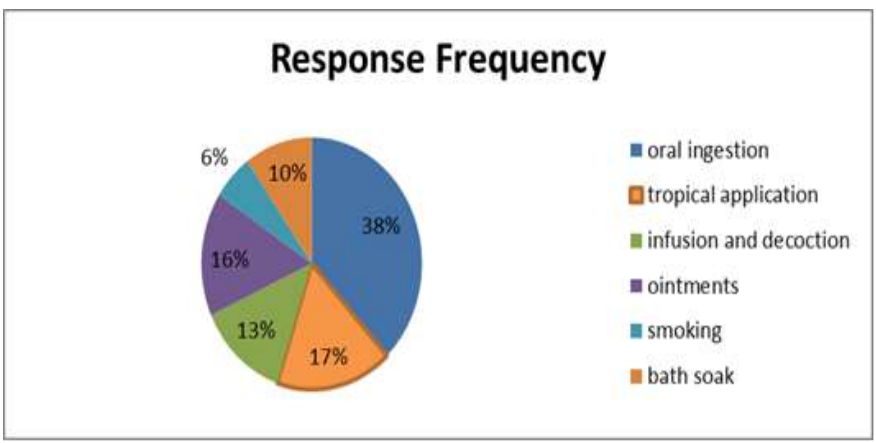

Figure 1. Responses frequency on method of administering medicinal insects

The pie chart in figure 1 shows that 101 respondents representing 38.4% administered medicinal insects by oral ingestion, 45 respondents representing 17.1% administered medicinal insects by tropical application, 35 respondents representing 13.3% administered medicinal insects by infusion and decoction, 42 respondents representing 16% administered medicinal insects by smoking while 25 respondents representing 10% administered medicinal insects by bath soak.

Table 3. How did you learn about the medicinal uses of insects?

Item	Frequency	Percentage (%)
Family	97	65%
Elders in community	32	21%
Traditional healers	09	06%
Social medial	12	8%
Total	**150**	**100%**

Table 3 revealed that 65% of the respondents learn about medicinal insects from family, 21% of the respondents learn about medicinal insects from elders in the community, 6% of the respondents learn about medicinal insects from traditional healers while 08% of the respondents learn about medicinal insects from social medial.

Table 4. Are there specific practices associated with the use of these medicinal insects?

Item	Frequency	Percentage (%)
Yes	0	0%
No	150	100%
Total	150	100%

Table 4 revealed that 100% of the respondents affirm that there are no specific rituals or practices associated with the use of these medicinal insects.

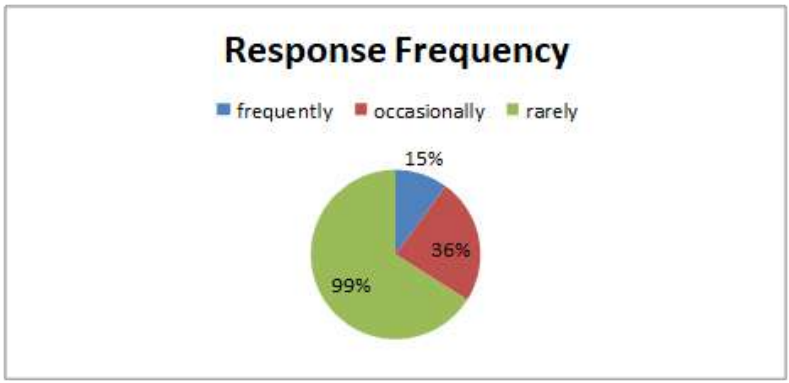

Figure 2. Responses frequency of how medicinal insects are used for treating insects

The pie chart in figure 2 shows responses frequency of how frequently medicinal insects are used for treating insects, 15 of the respondents representing 360 frequently used medicinal insects, 36 of the respondents representing 86.40 used medicinal insects occasionally while 99 respondents representing 237.60 rarely used medicinal insects.

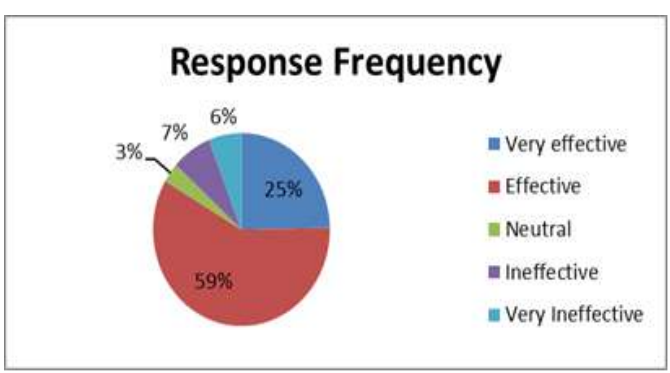

Figure 3. Responses frequency on effective of medicinal insects in treating ailments

Figure 3 affirmed that 125 respondents representing found medicinal insects to be effective, 5 respondents found medicinal insects to be neutral while 20 respondents found medicinal insects to be ineffective.

3. DISCUSSION OF FINDINGS

The data reveals a rich variety of medicinal practices involving insects among the respondents. Notably, honeybees were used by the most individuals (150 respondents, or 19.2%), followed by termites (93 respondents, 11.9%) and mole crickets (101 respondents, 12.9%). Other commonly used insects included caterpillars, silkworms, ants, and cockroaches, with each serving distinct roles in traditional medicine.

Preparation methods show some commonalities: termites, ants, mole crickets, and grasshoppers are often prepared similarly, while caterpillars, silkworms, cockroaches, and water bugs share another set of methods. Honeybees stand out as they are uniquely processed through honey harvesting and the use of bee brood.

The most frequently reported way to use these medicinal insects is through oral ingestion, chosen by 101 respondents (38.4%). Other methods include topical applications, infusions, smoking, and bath soaking.

Knowledge about these practices predominantly comes from family members (65%), with others learning from community elders, traditional healers, or social media. Interestingly, all respondents reported that there are no specific rituals associated with using these insects, indicating a more practical approach focused on their therapeutic benefits rather than cultural ceremonies.

A significant number of people (66%) have used cockroaches or related products, reflecting a cultural acceptance of these non-conventional remedies.

The perceived effectiveness of medicinal insects is largely positive, with 125 respondents considering them effective, while only 20 found them ineffective.

Overall, these findings shed light on the role of insects in traditional healing and suggest meaningful areas for future research into their potential benefits in modern medicine.

CONCLUSION

Based on the findings of this study, the researcher concluded that the entomotherapy assessment of medicinal insects within Abeokuta metropolis, particularly in the Abeokuta metropolis, are well preserved by people within the geographical location due to its importance.

The survey data recorded that a significant majority of respondents (125 out of 150) in the Abeokuta metropolis area have believe that medicinal insects are effective. The primary source of knowledge about these insects is the family (65%), followed by elders in the community (21%), suggesting that traditional knowledge is passed down through generations. Oral ingestion is the most common method of administering medicinal insects (38.4%), followed by topical application (17.1%). While a slight majority (97 respondents) indicated they do not face challenges when using medicinal insects, a substantial number (53 respondents) do report facing difficulties. Furthermore, the community is divided on whether the knowledge of medicinal insects is being adequately preserved, with 88 agreeing and 67 disagreeing. This highlights a need for efforts to document and promote this traditional knowledge, and to address the challenges faced by those who use medicinal insects as medicine to ensure its continued use and potential integration into modern healthcare practices."

Conflict Of Interest

Authors declare that no conflict of interest exist or competing interest among the authors.

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ISBN: 978-625-92238-8-9