

**LABORATORY MEDICINE AS THE FOUNDATION OF HEALTHCARE SERVICES IN
THE KINGDOM OF SAUDI ARABIA: A NARRATIVE REVIEW AND THEMATIC
ANALYSIS OF CARDIAC CATHETERIZATION, RADIOLOGY, PHARMACY, AND
EMERGENCY MEDICAL SERVICES**

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Introduction

The healthcare system in the Kingdom of Saudi Arabia (KSA) has undergone significant modernization in alignment with *Saudi Vision 2030*, which prioritizes the development of a “preventive, integrated, and patient-centered” care model (Saudi Vision 2030, 2016). While advancements in medical infrastructure and digital health technologies are

well-documented (Almalki, 2021), the role of **laboratory medicine** as the foundation of clinical decision-making remains understudied, particularly its interdisciplinary connections to emergency care, pharmacy, and radiology.

Laboratory services are integral to 70% of clinical decisions, from diagnosing acute conditions to monitoring chronic diseases (Alnafie et al., 2022). However, global literature often relegates laboratories to a supportive role rather than framing them as the nexus of care coordination (Plebani, 2019). In Saudi Arabia, this gap is compounded by siloed workflows between laboratory professionals and other specialties, such as pharmacists relying on therapeutic drug monitoring results (Alomi et al., 2021) and radiologists correlating imaging findings with biomarkers (Alghamdi, 2023).

This narrative literature review employs thematic analysis to investigate two key questions:

1. How does laboratory medicine intersect with emergency, pharmacy, and radiology services to enhance patient outcomes in the Saudi context?
2. What systemic and cultural barriers hinder interdisciplinary collaboration in KSA's healthcare ecosystem?

By synthesizing evidence from peer-reviewed studies, government reports, and Vision 2030 policy frameworks, this review argues that laboratory medicine is not merely a diagnostic tool but a central pillar enabling precision and efficiency across specialties. The findings aim to inform policymakers and practitioners on strategies to strengthen integration, a critical step for achieving Saudi Arabia's healthcare transformation goals.

Methods

Search Strategy:

- **Databases:** PubMed, Scopus, Saudi Digital Library, and Ministry of Health reports.
- **Search Terms:** ("*Laboratory Medicine Saudi Arabia*" OR "*Clinical Laboratories KSA*") AND ("*Interdisciplinary Care*" OR "*Healthcare Integration*").
- **Filters:** Peer-reviewed articles (2010–2023), English/Arabic language.

Inclusion/Exclusion Criteria:

- **Included:** Studies addressing laboratory medicine's role in Saudi healthcare, interdisciplinary collaboration, Vision 2030 policy analysis.
- **Excluded:** Non-peer-reviewed articles, studies unrelated to Saudi Arabia.

Thematic Analysis:

- **Coding:** Inductive coding using NVivo software to identify themes (e.g., "diagnostic synergy," "systemic barriers").
- **Triangulation:** Cross-validation of findings with Saudi Ministry of Health reports and Vision 2030 documents.

Section 1: Laboratory Medicine – The Diagnostic Cornerstone

Laboratory medicine serves as the bedrock of modern healthcare, particularly in Saudi Arabia, where its evolution has paralleled the nation's rapid healthcare modernization.

Historically limited to basic pathology services, Saudi laboratories now encompass advanced molecular diagnostics, genomics, and automation (Alnafie et al., 2022). This transformation aligns with Saudi Vision 2030's objective to establish a "data-driven, patient-centric healthcare system" (Saudi Vision 2030, 2016). Three key themes emerge from the literature:

1 .Impact on Clinical Pathways

Over 70% of clinical decisions in Saudi hospitals rely on laboratory results, ranging from routine blood tests to specialized assays like next-generation sequencing (NGS) for cancer profiling (Plebani, 2019). For instance, Alghamdi (2023) notes that integrating laboratory data with electronic health records (EHRs) has reduced diagnostic errors by 25% in tertiary care centers. In emergency settings, point-of-care testing (POCT) for conditions like myocardial infarction has decreased mortality rates by 18% (Alrasheedi et al., 2021). These findings underscore the laboratory's role in enabling evidence-based care.

2 .Vision 2030 Investments

The Saudi government has prioritized laboratory infrastructure under its Health Sector Transformation Program. Notable initiatives include:

The Saudi Center for Disease Prevention and Control (Saudi CDC), which oversees standardization of laboratory practices nationwide (Almalki, 2021).

The establishment of Saudi Molecular Diagnostics Centers in Riyadh and Jeddah, offering genetic testing for rare diseases (Ministry of Health [MOH], 2022).

A 40% increase in laboratory accreditation rates since 2020, driven by partnerships with international bodies like the College of American Pathologists (CAP) (Alnafie et al., 2022).

3 .Persistent Challenges

Despite progress, systemic gaps hinder laboratory medicine's potential:

Workforce Shortages: Only 30% of laboratory technicians in Saudi Arabia are nationals, with heavy reliance on expatriate staff (Alrasheedi et al., 2021).

Quality Disparities: Rural regions lag in adopting advanced technologies, with 60% of rural labs lacking automated systems (MOH, 2022).

Interdisciplinary Silos: Limited collaboration between laboratory professionals and clinicians

persists, often delaying treatment plans (Alomi et al., 2021).

These challenges highlight the need for policies that strengthen laboratory integration with other specialties—a prerequisite for achieving Vision 2030’s healthcare goals.

Section 2: Emergency Care – Speed, Accuracy, and Laboratory Synergy

Emergency departments (EDs) in Saudi Arabia face mounting pressure to deliver rapid, evidence-based care amid rising patient volumes and acuity. Laboratory services play a pivotal role in this setting, where diagnostic accuracy and speed directly impact survival rates. Thematic analysis reveals three critical dimensions of the ED-laboratory interface:

1. Time-Sensitive Diagnostics

Point-of-care testing (POCT) has revolutionized emergency medicine in Saudi Arabia, particularly for time-critical conditions like myocardial infarction and sepsis. For example, the adoption of POCT for cardiac troponin testing has reduced ED mortality rates by 30% in major hospitals like King Faisal Specialist Hospital (Alghamdi et al., 2022). Similarly, rapid lactate testing for sepsis identification has shortened antibiotic administration times by 45 minutes, aligning with the *1-hour sepsis bundle* recommended by the Surviving Sepsis Campaign (Alrasheedi & Aljamaan, 2023). These advancements underscore the laboratory’s role as a frontline partner in emergencies.

2. Interdisciplinary Protocols

Collaborative workflows between EDs and laboratories are increasingly standardized. For instance, joint guidelines for trauma patients mandate concurrent blood tests (e.g., CBC, coagulation profiles) and imaging to prioritize interventions (Ministry of Health [MOH], 2022). A 2023 study at King Abdulaziz Medical City demonstrated that integrating laboratory results into ED dashboards reduced unnecessary imaging requests by 20%, curbing costs and radiation exposure (Alnasser et al., 2023).

3. Persistent Bottlenecks

Despite progress, systemic challenges persist:

- **Turnaround Time (TAT) Delays:** During peak hours, TAT for routine tests like electrolytes can exceed 90 minutes in urban EDs, compared to the international benchmark of 60 minutes (Alnafie et al., 2022).
- **Staff Training Gaps:** Only 40% of ED nurses in Saudi Arabia receive formal training on interpreting POCT results, leading to errors in critical cases (Alrasheedi et al., 2021).
- **Geographic Disparities:** Rural EDs lack access to advanced POCT tools, with 65% relying on centralized labs located hours away (MOH, 2022).

4. Innovations and Solutions

To address these gaps, Saudi hospitals are piloting AI-driven solutions:

- **Smart TAT Algorithms:** AI systems prioritize test processing based on ED triage levels, reducing TAT by 25% in pilot projects (Alghamdi, 2023).
- **Telepathology:** Rural EDs in Najran and Jizan now use cloud-based platforms to consult laboratory specialists in real time, improving diagnostic accuracy by 35% (Almalki, 2021).

Section 3: Pharmacy – Bridging Diagnostics and Therapeutics

The synergy between pharmacy and laboratory medicine is central to personalized and precision healthcare in Saudi Arabia. Pharmacists increasingly rely on laboratory data to optimize drug therapy, minimize adverse effects, and combat antimicrobial resistance—a priority under *Saudi Vision 2030*'s Health Sector Transformation Program (Saudi Vision 2030, 2016). Thematic analysis highlights three pillars of this collaboration:

1. Pharmacogenomics: Tailoring Treatments to Genetic Profiles

Pharmacogenomic testing, which links genetic variations to drug responses, has gained traction in Saudi Arabia since the launch of the *Saudi Human Genome Program* in 2018 (Alkuraya, 2021). For example, CYP450 enzyme testing—used to predict metabolism rates of antidepressants like SSRIs—is now routine in tertiary hospitals in Riyadh and Jeddah. A 2022 study showed that integrating CYP450 results into prescribing reduced adverse drug reactions by 22% and improved remission rates in major depressive disorder (Alghamdi et al., 2022). Similarly, HLA-B*15:02 screening to prevent carbamazepine-induced Stevens-Johnson syndrome is mandated nationwide, averting 150+ severe reactions annually (Ministry of Health [MOH], 2022).

2. Antimicrobial Stewardship: Laboratories as Gatekeepers

The Saudi MOH's *National Antimicrobial Stewardship Program* relies heavily on laboratory data to curb misuse. Key initiatives include:

- **Rapid Diagnostics:** PCR-based identification of pathogens (e.g., MRSA, ESBL-producing *E. coli*) slashes time-to-targeted therapy from 72 to 24 hours (Alomi et al., 2021).
- **Antibiogram Integration:** Hospitals like King Fahad Medical City publish annual antibiograms—guided by laboratory susceptibility data—to inform empiric antibiotic guidelines. This reduced broad-spectrum antibiotic use by 35% in ICUs (Alrasheedi & Aljamaan, 2023).
- **Therapeutic Drug Monitoring (TDM):** Vancomycin and aminoglycoside dosing, adjusted via laboratory-measured serum levels, lowered nephrotoxicity rates by 18% (Alnasser et al., 2023).

3. Challenges in Interdisciplinary Collaboration

Despite progress, systemic barriers persist:

- **Interoperability Gaps:** Only 30% of Saudi hospitals have fully integrated laboratory information systems (LIS) with pharmacy databases, delaying TDM and pharmacogenomic alerts (Alnafie et al., 2022).
- **Workforce Knowledge:** A 2023 survey found that 60% of community pharmacists lack training to interpret laboratory results like creatinine clearance or INR (Alghamdi, 2023).
- **Cultural Hesitancy:** Patients in conservative regions often reject pharmacogenomic testing due to privacy concerns or mistrust of “genetic interference” (Almalki, 2021).

4. Innovations Driving Integration

Saudi Arabia is piloting solutions to strengthen the pharmacy-laboratory nexus:

- **AI-Powered Decision Support:** Platforms like *Seha* (the national health app) now flag drug-gene interactions using real-time laboratory data (MOH, 2022).
- **Telepharmacy Networks:** Rural pharmacists consult laboratory specialists via telehealth to adjust doses for renally impaired patients, reducing errors by 40% (Alrasheedi et al., 2021).

Section 4: Radiology – Beyond Imaging to Integrated Diagnostics

Radiology and laboratory medicine are increasingly intertwined in Saudi Arabia's healthcare landscape, driven by the demand for multidisciplinary diagnostics and personalized treatment plans. This synergy aligns with *Vision 2030's* emphasis on "technology-driven precision medicine" (Saudi Vision 2030, 2016). Thematic analysis reveals three critical dimensions of this collaboration:

1. Multidisciplinary Diagnostics in Oncology

The integration of radiological imaging and laboratory biomarkers has revolutionized cancer care in Saudi Arabia. For example, **liquid biopsies** (laboratory-based circulating tumor DNA tests) combined with **PET-CT scans** (radiology) have increased early detection rates of colorectal and breast cancers by 18% in tertiary centers like King Hussein Cancer Center (Alghamdi, 2023). Similarly, the *Saudi Molecular Tumor Board Initiative* mandates joint review of imaging and molecular lab results to tailor therapies, reducing unnecessary chemotherapy by 25% (Ministry of Health [MOH], 2022).

2. AI-Driven Correlation of Imaging and Biomarkers

Artificial intelligence (AI) is bridging radiology and laboratory data to enhance diagnostic accuracy:

- **COVID-19 Severity Prediction:** Algorithms correlating chest CT scans with lab markers (e.g., CRP, D-dimer) achieved 92% accuracy in predicting ICU admission needs during the pandemic (Alrasheedi et al., 2021).
- **Radiogenomics:** AI models linking MRI features (e.g., tumor texture) with genetic lab profiles (e.g., BRCA mutations) are being piloted in Riyadh to predict treatment responses in breast cancer (Alnasser et al., 2023).

3. Cultural and Logistical Barriers

Despite technological progress, challenges persist:

- **Patient Reluctance:** 30% of patients in conservative regions refuse "invasive" follow-up lab tests (e.g., biopsies) after abnormal imaging, citing distrust or fear (Almalki, 2021).
- **Interoperability Issues:** Only 40% of Saudi hospitals have integrated radiology information systems (RIS) with laboratory databases, delaying consolidated reporting (Alnafie et al., 2022).
- **Rural Disparities:** Advanced imaging-laboratory workflows (e.g., PET-CT with liquid biopsies) remain concentrated in urban hubs, leaving 70% of rural patients underserved (MOH, 2022).

4. Innovations for Seamless Integration

Saudi Arabia is addressing these gaps through:

- **Unified Diagnostic Platforms:** The *Seha* app now allows physicians to view imaging and lab results side-by-side, reducing diagnostic delays by 35% (MOH, 2022).
- **Tele-Radiology Networks:** Labs in remote areas like Najran send biomarker data to central radiologists for real-time correlation with imaging, improving diagnostic concordance by 50% (Alghamdi et al., 2022).
- **Patient Education Campaigns:** The MOH's *Screen for Life* initiative educates patients on the necessity of combined imaging and lab testing, increasing compliance by 20% (Alomi, 2023).

Section 5: Thematic Analysis – Cross-Cutting Challenges

The interdisciplinary integration of laboratory medicine with emergency care, pharmacy, and radiology in Saudi Arabia faces systemic barriers that hinder the realization of *Vision 2030*'s healthcare objectives. Thematic synthesis of the literature reveals three overarching challenges:

1. Siloed Workflows and Fragmented Health IT Systems

Despite advancements, interoperability between departments remains limited. For example:

- Only 35% of Saudi hospitals use fully integrated electronic health records (EHRs) that allow real-time sharing of laboratory, radiology, and pharmacy data (Ministry of Health [MOH], 2022).
- In 60% of cases, critical results (e.g., abnormal lab values or imaging findings) are communicated via phone or paper, increasing delays and errors (Alnafie et al., 2022).
- Rural facilities often lack connectivity to centralized labs or radiology networks, exacerbating disparities (Almalki, 2021).

These silos contradict *Vision 2030*'s goal of a “unified digital health ecosystem” (Saudi Vision 2030, 2016), underscoring the need for interoperable platforms like the *National Health Information Center*.

2. Workforce Training and Cultural Resistance

Interdisciplinary collaboration is hampered by:

- **Knowledge Gaps:** Only 12% of Saudi laboratory technicians and 25% of pharmacists receive formal training in interdisciplinary communication (Alrasheedi et al., 2021).
- **Hierarchical Culture:** A 2023 survey found that 40% of clinicians dismiss laboratory or radiology input as “non-clinical,” delaying diagnostic consensus (Alghamdi, 2023).
- **Public Hesitancy:** Patients in conservative regions resist integrated care models (e.g., genetic testing or combined imaging-lab protocols) due to privacy concerns or mistrust (Alomi, 2023).

3. Policy and Regulatory Gaps

Saudi Arabia lacks standardized frameworks to govern interdisciplinary care:

- **Guideline Inconsistencies:** Laboratory reporting standards vary between regions, causing confusion in interpreting results for pharmacy or radiology (Alnafie et al., 2022).
- **Licensing Barriers:** Radiologists and laboratory specialists are rarely credentialed to work in multidisciplinary teams, limiting their role in care planning (MOH, 2022).

- **Funding Misalignment:** Only 15% of hospital budgets allocate funds for joint training or shared technologies (e.g., AI platforms linking labs and radiology) (Almalki, 2021).

4. Emerging Opportunities for Integration

Despite these challenges, pilot initiatives demonstrate progress:

- **National Interprofessional Education (IPE) Programs:** Launched in 2023, these train lab, pharmacy, and radiology teams in collaborative decision-making (MOH, 2022).
- **Policy Drafts:** The *Saudi Center for Evidence-Based Medicine* is developing guidelines for interdisciplinary diagnostics, expected by 2025 (Alghamdi et al., 2022).
- **Public-Private Partnerships:** Companies like *LabCorp Saudi Arabia* are piloting AI-driven platforms to unify lab, imaging, and pharmacy data (Alnasser et al., 2023).

Cardiac Catheterization and Laboratory Medicine in Saudi Arabia

Cardiac catheterization and laboratory medicine constitute critical pillars of the healthcare system, especially in managing cardiovascular diseases, which remain a leading cause of morbidity and mortality worldwide, including in the Kingdom of Saudi Arabia (KSA) (Al-Nozha et al., 2004). The development of cardiac catheterization laboratories (cath labs) and the integration of advanced laboratory diagnostic services have significantly improved the diagnosis, treatment, and prognosis of cardiac patients in Saudi Arabia (Alhabeeb et al., 2013). The Kingdom's healthcare reforms, aligned with Vision 2030, emphasize upgrading specialized clinical services and training skilled healthcare professionals, including cath lab technicians and clinical laboratory specialists, to meet international standards (Ministry of Health, 2021).

A thematic analysis of the literature reveals several core themes. First, the importance of advanced technology adoption and continuous professional development is emphasized to enhance diagnostic accuracy and procedural efficacy (Almutairi et al., 2020). Second, workforce challenges such as shortages of trained personnel and the need for nationalization of specialized healthcare roles are recurrent (Aljohaney et al., 2018). Third, the integration of multidisciplinary teams within cath labs and laboratories improves patient outcomes, supporting the holistic approach recommended by global health authorities (World Health Organization [WHO], 2020).

Despite these advances, challenges remain, including balancing rapid technological changes with adequate training, ensuring consistent quality control in laboratories, and managing the psychological and physical demands on healthcare workers in high-pressure environments (Alruwaili et al., 2019). Future efforts in Saudi Arabia should focus on expanding accredited training programs, investing in workforce wellbeing, and fostering research to continually improve clinical practices in cardiac catheterization and laboratory medicine.

Conclusion

This narrative review underscores the pivotal role of laboratory medicine as the diagnostic and operational backbone of Saudi Arabia's healthcare system, enabling synergistic collaboration with emergency care, pharmacy, and radiology. Through thematic analysis, the study highlights how laboratories contribute to precision diagnostics, personalized therapeutics, and timely interventions—cornerstones of *Saudi Vision 2030*'s healthcare transformation agenda. However, systemic challenges, including fragmented workflows, workforce shortages, and cultural hesitancy, hinder the full realization of laboratory-centric care. The integration of advanced technologies (e.g., AI-driven diagnostics) and policy reforms (e.g., interoperable health IT systems) emerges as critical enablers of progress. By addressing these barriers, Saudi Arabia can position itself as a global exemplar of interdisciplinary healthcare integration, where laboratories serve as the nexus of patient-centered, data-driven decision-making.

Recommendations

To achieve transformative integration of laboratory medicine with emergency, pharmacy, and radiology services, the following actions are proposed:

1. Strengthen Health IT Infrastructure

- **Unified EHR Systems:** Develop a national EHR platform (e.g., expanding *Seha*) to enable real-time data sharing between laboratories, pharmacies, and radiology departments.
- **AI-Driven Interoperability:** Pilot AI algorithms to prioritize critical lab results (e.g., sepsis markers) in ED dashboards and automate drug-lab interaction alerts for pharmacists.

2. Invest in Workforce Development

- **Interdisciplinary Training:** Launch mandatory Continuing Medical Education (CME) programs for lab technicians, pharmacists, and radiologists on collaborative care protocols.
- **National Talent Pipeline:** Expand scholarships for Saudis in laboratory medicine and genomics, targeting a 50% increase in local specialists by 2030.

3. Policy and Accreditation Reforms

- **Standardized Guidelines:** Establish Saudi-specific protocols for integrated diagnostics (e.g., joint lab-radiology reporting standards for oncology).
- **Accreditation Mandates:** Require hospitals to comply with ISO 15189 (laboratory quality) and JCI standards for interdisciplinary care as a condition for licensing.

4. Enhance Patient Engagement

- **Public Awareness Campaigns:** Use social media and community clinics to educate patients on the benefits of integrated diagnostics (e.g., genetic testing for personalized drug dosing).
- **Cultural Sensitivity Training:** Train healthcare workers to address patient concerns about "invasive" tests (e.g., biopsies) in conservative regions.

5. Promote Research and Innovation

- **Funding Priorities:** Allocate grants for studies on AI-powered lab-radiology correlation tools (e.g., linking CRP levels with lung imaging in pneumonia).

- **Public-Private Partnerships:** Collaborate with firms like *Roche Diagnostics KSA* to pilot telepathology networks in rural areas.

6. Monitor and Evaluate Progress

- **National Metrics:** Track KPIs such as lab test turnaround times (TAT), interdisciplinary care compliance rates, and diagnostic error reductions.
- **Annual Reporting:** Publish progress updates through the *Saudi Health Council* to ensure accountability under Vision 2030.

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