Navigating professional boundaries and relational dynamics in medical imaging innovation: the contested adoption of PET-CT in oncology

1. Introduction: The paradox of hybrid innovation

Positron Emission Tomography-Computed Tomography (PET-CT) has fundamentally altered oncological decision-making by combining functional and anatomical data into a single hybrid modality. The clinical utility of PET-CT is widely recognized; for instance, prospective data from the National Oncologic PET Registry (NOPR) indicate that physicians modify their intended therapeutic management in nearly 50% of treatment-monitoring cases following a PET scan, often adjusting the dose or duration of therapy or switching to another therapeutic class (Hillner et al., 2009).

However, in France, the integration of this "one-stop-shop" technology is characterized by a highly heterogeneous and often contested adoption. The variability of the so-called “hybrid practice” is a pivotal element in the present investigation, as the thoroughness of CT interpretation directly impacts diagnostic performance and patient management. This variability is rooted in the distinctive structure of the French healthcare system, where nuclear medicine (NM) and radiology have historically operated with distinct training pathways and professional identities. French context is particularly illustrative of the tensions that arise when technical innovation outpaces organizational and professional evolution. Despite the technology's theoretical potential, the effective integration of all relevant imaging data to support complex therapeutic decisions is frequently stymied by what sociologists term "medical professionalism" - the norms used to establish authority and control over work.

Our study focuses on the specific multi-jurisdictional context of French medical imaging. We place referring clinicians (oncologists, radiotherapists or surgeons) at the center of our analysis, identifying them as the ultimate gatekeepers of the technology. The persistent skepticism among these gatekeepers regarding PET-CT's diagnostic superiority over conventional CT in specific scenarios highlights a critical challenge for the diffusion of this innovation. Such skepticism frequently finds its genesis in rigorous adherence to the tenets of Evidence-Based Medicine (EBM), where clinicians demand clear proof that the technology will demonstrably alter their therapeutic approach before integration. Our research explore the socio-organizational factors -

perceptions, expectations, and interprofessional dynamics - that shape the diffusion trajectory of PET-CT, bridging the gap between technological potential and diagnostic reality, and finally hindering or promoting PET-CT adoption.

Commenté [BG1]: Il manque le plan de la communication

To achieve this, this article is structured as follows:

- Section 2 outlines our multi-theoretical framework, which combines Rogers' diffusion of innovation, boundary sociology (boundary objects and boundary work), and social exchange theory to move beyond purely individualistic models of technology acceptance toward a systemic understanding.
- Section 3 details our qualitative, interpretivist methodology, describing the cohort of clinicians interviewed across two Comprehensive Cancer Centers and our rigorous two-stage AI-assisted thematic analysis.
- Section 4 presents the research results, unpacking the duality of forces shaping PET-CT adoption by contrasting the drivers of integration (such as perceived clinical value, ease of access, and interpersonal trust) with the primary structural barriers (inadequate reports, skill gaps, and entrenched professional silos).
- In section 5, we discuss these findings, specifically analyzing the PET-CT report through the lens of a boundary object, demonstrating how perceived technical inadequacies are actually rooted in boundary work and jurisdictional struggles.
- Based on this theoretical diagnosis, section 6 proposes actionable managerial implications and strategies, including re-engineering medical reports into true expert consultations, fostering proactive cross-disciplinary collaboration, and strategically preparing for the upcoming Radioligand Therapy (RLT) transition.
- Finally, section 7 concludes the paper, acknowledging the limitations of our qualitative sample and outlining avenues for future research and replication.

2. Theoretical framework: diffusion of innovation and boundary work

Our study utilizes established social science theories to interpret the complex interplay of factors conditioning the integration of hybrid imaging (PET-CT) in oncology. Addressing ongoing debates in healthcare innovation management, we purposefully move away from purely individualistic, rational-choice models of technology acceptance, such as Davis' Technology Acceptance Model (TAM; Davis, 1989). While TAM assumes that "perceived usefulness" and "perceived ease of use" autonomously drive individual behavior, it fails to capture the deeply entrenched inter-

organizational networks and structural constraints of healthcare. Instead, we propose a systemic, multi-theoretical framework anchored in three complementary pillars: organizational diffusion of innovation, boundary sociology, and social exchange theory.

Diffusion of Innovation (DoI):

We utilize Rogers' seminal framework to understand the intrinsic attributes of PET-CT within existing clinical workflows (Rogers, 1983). According to Rogers, adoption rates are heavily dictated by gatekeepers' perceptions of an innovation's relative advantage (its clinical superiority), compatibility (its alignment with established evidence-based medicine norms and professional values), and complexity (the perceived cognitive effort required to interpret the hybrid data. However, to tailor this to the healthcare context, we integrate Greenhalgh's systematic model of diffusion in service organizations (Greenhalgh et al., 2004). Greenhalgh and colleagues warn against the pro-innovation bias prevalent in early diffusion research - the erroneous assumption that an innovation is inherently beneficial and that its adoption is a simple, linear process of communication.

In complex professional institutions like French Comprehensive Cancer Centers (CCC), adoption is not an individual event but a non-linear process of assimilation by the system. To achieve successful integration, it is essential to consider innovation-system fit. This entails ensuring that the technology is adaptable to the socio-organizational dimensions, i.e. the local organizational structures, skill mixes, and routines required for implementation. This aligns with the sociotechnical perspective, which Sarker et al. (2019) position as the fundamental axis of cohesion for understanding technology integration. According to this approach, neither the technical artifact nor the human activity deserves a privileged position; rather, it is the continuous, dynamic interplay between the two that shapes ongoing practice. Therefore, if an innovation like PET-CT is not compatible with the existing socio-political climate or inter-organizational norms, its technical relative advantage will be systematically overridden by structural resistance.

Commenté [BG2]: Faire explictement à l'approche socio-technique
Sarker, S., Chatterjee, S., Xiao, X., & Elbanna, A. (2019). The sociotechnical axis of cohesion for the IS discipline: Its historical legacy and its continued relevance. MIS Quarterly, *43*(3), 695–720.

Boundary objects and boundary work:

To illuminate the professional dynamics that modulate this diffusion, we mobilize the concepts of boundary objects (Star & Griesemer, 1989) and boundary work (Gieryn, 1983; Abbott, 1988) Scientific and medical work is fundamentally heterogeneous, requiring cooperation among diverse actors (e.g., nuclear physicians, radiologists, oncologists) who inhabit different social worlds.

Star and Griesemer developed the concept of the boundary object to explain how these heterogeneous actors achieve cooperation without requiring full consensus. Boundary objects - such as the PET-CT medical report - are artifacts that inhabit intersecting social worlds; they must be plastic enough to adapt to the local, specialized needs of the oncologist, yet robust enough to maintain a common scientific identity across the imaging specialties. Successful diffusion relies on an "n-way translation" where the concerns of all participants are adequately represented in the object.

Conversely, boundary work describes the ideological efforts and rhetorical styles by which professionals construct social boundaries to demarcate their expertise from others (Gieryn, 1983). As Abbott notes in his system of professions, specialized groups actively engage in boundary work to monopolize authority, protect autonomy, and defend their professional jurisdictions against encroachment. To bridge the gap between boundary objects and boundary work, we embed Carlile's concept of pragmatic boundaries (Carlile, 2002). Specialized knowledge in an organization is both a critical source of innovation and a fundamental barrier to it. Within medical imaging specialties like NM or radiology, knowledge is localized, embedded, and invested in practice. Because medical professionals are heavily invested in their hard-won outcomes and routines, their specialized knowledge is at stake when forced to interact with the demands of another discipline. In the highly specialized medical field, crossing the nuclear medicine/radiology boundary requires more than a simple syntactic transfer of images and the pragmatic Carlile's view of knowledge might explain why; a pragmatic boundary object capable of transforming knowledge may resolve the innovation's perceived incompatibility.

Social exchange theory:

Finally, we incorporate social exchange theory (Blau, 1964; Emerson, 1976) to examine the micro-relational dynamics that sustain these boundaries. We examine the role of trust, reciprocity, and the perceived balance of costs and benefits in interprofessional collaborations. Unlike formal economic contracts, Blau argues that social exchange is built on unspecified obligations. When an oncologist refers a patient for a PET-CT, there is an implicit expectation that the imaging specialist will reciprocate with a highly contextualized, decisive interpretation. If the NM physician provides a fragmented report, this lack of reciprocity violates the social exchange, generating a perception of high cost - increased cognitive effort - for the oncologist, thereby eroding interprofessional trust.

The mobilization of these frameworks demonstrates how the intrinsic characteristics of the PET-CT innovation interact dynamically with the boundary work occurring between NM and radiology. Specifically, the inadequacy of medical reports translates into a perceived complexity of the hybrid data, while jurisdictional uncertainty reveals the incompatibility of PET-CT with established professional boundaries - acting as two major structural barriers to diffusion.

3. Methodology

We employed a qualitative, interpretivist approach to capture PET-CT adoption as a lived and socially situated process within the specificities of the French oncological setting

Participants and study design: semi-structured individual interviews were conducted in two French Comprehensive Cancer Centers (CCC). The sample size (n=13) was determined using the concept of "information power", which posits that a highly specific group of gatekeepers with extensive experience provides high information density, reducing the need for a larger sample. Participants included 6 medical oncologists, 4 radiotherapists, 2 surgeons, and 1 radiologist. The cohort (6 women, 7 men) had an average age of 43.6±7.5 years and 11.2±5.9 years of post-specialization clinical experience. Detailed characteristics are provided in **Erreur ! Source du renvoi introuvable.**.

Table 1: characteristics of studied population.

Comprehensive cancer center sites (S1 or S2)	Respondents	Gender	Age category, delineated by decade (years)	Clinical specialty	Duration of interview (minutes)
S1	R1	M	> 50	Medical oncology	54
S1	R2	F	> 50	Radiology	59
S1	R3	M	40 - 50	Radiation therapy	54
S1	R4	M	40 - 50	Medical oncology	49
S1	R5	M	40 - 50	Medical oncology	63

S1	R6	M	> 50	Radiation therapy	48
S1	R7	F	40 - 50	Medical oncology	40
S1	R8	F	30 - 40	Medical oncology	48
S2	R9	M	30 - 40	Radiation therapy	58
S2	R10	M	30 - 40	Surgery	66
S2	R11	F	30 - 40	Radiation therapy	51
S2	R12	F	30 - 40	Medical oncology	44
S2	R13	F	40 - 50	Surgery	69

Data collection:

Interviews averaged 54.1 minutes, were audio-recorded with informed consent, transcribed verbatim, and fully anonymized. A thematic interview guide explored participants' perceptions of PET-CT utility, prescription decisions, expectations regarding reports, and interprofessional dynamics.

Data analysis and AI visualization:

To ensure methodological rigor, we utilized a two-stage hybrid thematic analysis. To address reviewer requests for transparency regarding AI usage, the workflow is visualized in figure 1.

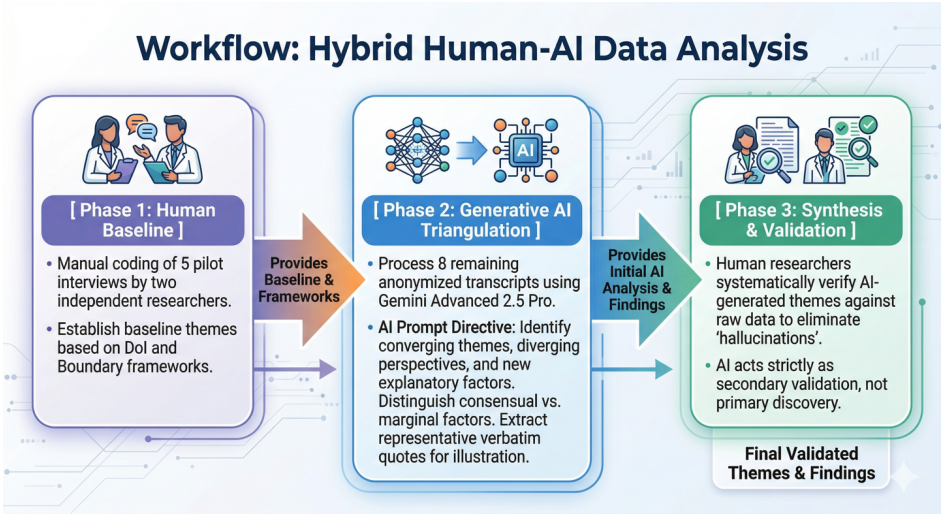

Figure 1: schematic representation of the analysis workflow (AI-built scheme). The AI was explicitly instructed to apply our predefined conceptual framework and output structured comparative findings. Data privacy was ensured using research-grade safeguards on fully anonymized text.

Ethical considerations:

All participants provided written informed consent. In accordance with French regulations for non-interventional research involving only healthcare professionals discussing their professional practice, formal ethics committee approval was not required. Data were fully anonymized to maintain confidentiality.

4. Research results: drivers and barriers of a contested adoption

The analysis revealed a complex interplay of factors influencing PET-CT adoption. Our findings demonstrate that referring oncologists are not passive recipients of a new technology; rather, they are active "gatekeepers" who dynamically co-construct the utility of PET-CT. The data exposes a duality of forces: factors actively promoting PET-CT use through perceived clinical value and social exchange, and profound structural barriers hindering its optimal integration through jurisdictional disputes and reporting inadequacies.

4.1 Factors promoting adoption: clinical value, access, social exchange

- Perception of high clinical value (relative advantage): adoption is heavily driven by the perceived ability of PET-CT to fundamentally alter therapeutic strategy, particularly in staging aggressive tumors. As surgeon R10 noted, *« it can change the therapeutic strategy (...) as soon as we have a lymph node (...) detected by PET (...) it makes us change our strategy ».* Furthermore, the visual simplicity of PET images - where metabolic hotspots light up distinctly - was frequently cited as a pragmatic accelerator for adoption by busy clinicians, even though some gatekeepers criticized this simplicity for potentially masking deeper diagnostic nuances.
- Ease of access as an organizational accelerator: our data reveals that practical, organizational constraints often override strict adherence to formalized clinical guidelines, confirming the necessity of Greenhalgh's innovation-system fit. Clinicians frequently reported substituting conventional CT with PET-CT when the latter offered quicker appointment times. This pragmatic use is heavily influenced by the regional availability of equipment and personnel. As oncologist R7 highlighted, *"At [site X] there is [...] a monstrous shortage of radiologists and [...] as a result, we do a lot of PET."* This demonstrates that the adoption of a hybrid technology is heavily dictated by the local organizational ecosystem and resource deficits in competing departments. Radiotherapist R11 confirmed: *"In practice, for us, access to PET is rather quicker than to a thoraco-abdominal-pelvic CT scan…that must also change things a bit in prescriptions".*
- The major role of social exchanges and interpersonal trust: moving beyond the technology's intrinsic features, close professional relationships and the ability to discuss complex cases directly with a responsive team act as crucial facilitators. Interpreted through SET (Blau, 1964), adoption is sustained when referring clinicians perceive a balance of costs and benefits in their interactions with imaging departments. Trust, a critical element in these exchanges, was consistently reported as being tied to the *individual* imaging specialist rather than the PET-CT technology itself. Oncologist R12 observed: *"You see that the quality of the report is not the same depending on who does [...] the exam."* Gatekeepers expect a reciprocal relationship where imaging specialists proactively clarify requests and provide context-aware, decisive interpretations. When this reciprocity is fulfilled, interprofessional trust deepens, accelerating the integration of the hybrid modality.

4.2 Factors hindering adoption: skepticism, complexity and boundaries

- Strict adherence to EBM and doubts about diagnostic value: counterbalancing the perceived benefits, a significant portion of clinicians act as strict gatekeepers by demanding rigorous Evidence-Based Medicine (EBM) proof before adopting the technology into routine follow-up care. If PET-CT does not demonstrably alter their therapeutic approach, its relative advantage is soundly rejected. Oncologist R5 stated: *"As long as it hasn't been demonstrated to me that an early PET changes my therapeutic strategy, I don't include it".* Similarly, regarding patient follow-up, oncologist R8 noted: *"I find that the classic CT scan gives us a very good assessment, so not necessarily a need for more".* This skepticism highlights that technological superiority is not assumed; it must continuously prove its compatibility with the oncologists' EBM-driven decision-making routines.
- Dissatisfaction with report quality and variability (complexity): A profound barrier to adoption is the perceived inadequacy of PET-CT medical reports. Clinicians expressed immense frustration with reports that present fragmented metabolic and anatomical data, effectively increasing the perceived complexity of the innovation. Oncologist R1 expressed this frustration with the lack of synthesis: *"Often, we get answers, it picks up, it doesn't pick up, it's hypermetabolic [...] Well, what else? What's the conclusion?"*. Furthermore, the lack of systematic provision of anatomical details and the hesitation to use CT contrast agents actively limits the technology's utility. Oncologist R12 highlighted the severe negative consequences of this fragmentation: *"I find the very negative side [...] is that we end up with an inflation of prescriptions for other exams to answer questions raised by the PET scan that we don't have [...] with the classic CT scan where the radiologists will decide a bit more than the nuclear physicians do".* This inflation of subsequent tests represents a severe breakdown in the "one-stop-shop" promise of the innovation.
- Entrenched professional boundaries and the skill gap (incompatibility): The historical separation between NM and radiology in France creates a perceived "skill gap". Referring clinicians believe NM physicians lack radiological expertise, undermining the "one-stop-shop" promise. Radiotherapist R3 noted*: "Nuclear medicine people haven't learned to read scans like radiologists and vice versa".* Respondents emphasized that this separation is reinforced by organizational inertia, distinct training curricula, and geographical isolation. Radiotherapist R9 stated: *"The [geographical] distance doesn't encourage [communication]".* Consequently, some participants felt NM departments actively maintain these boundaries as a "pré carré" (exclusive domain) to prevent encroachment by

radiology. This territorial boundary work fosters jurisdictional uncertainty and severely degrades the interprofessional trust required for collaborative innovation.

4.3 Radioligand Therapy (RLT): an anticipated disruption

While the current adoption of PET-CT is contested, gatekeepers widely recognize the impending arrival of Radioligand Therapy (RLT) - which pairs diagnostic imaging with targeted therapeutic radiopharmaceuticals - as a disruptive evolution. Even clinicians who expressed skepticism about PET-CT's current diagnostic utility acknowledged RLT's transformative potential. This shift will fundamentally challenge existing boundaries, requiring a massive "re-translation" of roles as NM physicians transition from diagnostic consultants to active therapeutic partners managing patient toxicities and long-term care. As radiotherapist R9 noted: *"I think it must be disruptive for nuclear medicine physicians because they're going to see sick patients [...] It's not certain they'll all be very proactive."* This anticipation underscores that if the current socio-organizational frictions surrounding PET-CT reporting and interprofessional trust are not resolved, the integration of RLT will face insurmountable structural resistance.

5. Discussion: connecting boundaries, complexity, and healthcare debates

Our findings bring crucial new empirical data to the management sciences field by radically redefining the role of the user in healthcare innovation. We demonstrate that end-users (referring oncologists) are not passive recipients or mere "laggards" in a diffusion curve, but rather strategic gatekeepers. The heterogeneous adoption patterns we observed are the direct consequence of an active negotiation process where gatekeepers continuously weigh the technology's theoretical relative advantage against pragmatic access constraints and relational deficits. This confirms Greenhalgh’s assertion that complex medical innovations cannot simply be pushed into a system based solely on technical efficacy; their assimilation requires a profound negotiation of professional identities.

Our study also confirms that the diffusion of complex innovations in service organizations relies on innovation-system fit. Much of the existing literature on technology adoption relies heavily on individualistic, rational-choice paradigms, most notably the Technology Acceptance Model (TAM) (Davis, 1989) which assumes that perceived usefulness and perceived ease of use automatically drive acceptance. Our research deepens the critique of TAM by emphasizing that in the highly interdependent context of French healthcare, an individual’s assessment of perceived usefulness

is consistently overridden by interprofessional territoriality and jurisdictional uncertainty. This proves that for complex hybrid technologies, relational dynamics and boundary work supersede individual cognitive acceptance models.

A boundary object in tension:

The PET-CT medical report is theoretically positioned to function as a boundary object bridging the distinct social worlds of NM and oncology (Star & Griesemer, 1989). Nonetheless, our evidence indicates that the report is deficient in its fulfillment of the aforementioned role. Because current reports lack an integrated synthesis of metabolic and anatomic findings, they function as siloed data rather than robust decision-making tools. This fragmentation significantly increases the perceived effort (complexity in Rogers' term) for the referring clinician.

Viewed through Carlile's typology (Carlile, 2002), the current fragmented PET-CT report offers no infrastructure for oncologists and nuclear medicine physicians to jointly transform their localized knowledge into a shared clinical pathway. Consequently it falls short of its integrative purpose, operating merely as a repository (a syntactic object) or a standardized form (a semantic object), rather than a pragmatic boundary object capable of transforming knowledge. Because the report cannot transform knowledge at this pragmatic boundary, the technology remains fundamentally incompatible with the oncologist's need for swift, evidence-based therapeutic decision-making.

Commenté [BG3]: En l'état, il constitue un objet de tension (malentendus, conflits d'interprétation), tensions potentielles liées aux usages différenciés de l'information. En qualifiant ainsi, c'est peut être moins fort que de parler d'échec ?

Boundary work disguised as technical inadequacy:

These tensions are deeply rooted in boundary work - the active maintenance of professional delineations to safeguard autonomy (Gieryn, 1983)(Abbott, 1988) NM physicians' perceived hesitation to fully embrace diagnostic CT interpretation is a direct manifestation of this jurisdictional struggle. Carlile's (2002) pragmatic perspective clarifies why this territorial boundary work is so resilient. Nuclear medicine physicians and radiologists are deeply "invested" in their historically separated practices. To fully integrate diagnostic CT interpretation would require them to alter their specialized methods, effectively putting their hard-won professional competency "at stake." Consequently, they are reluctant to accommodate the knowledge developed by the competing department.

We offer the novel insight that what managers frequently diagnose as a "technical insufficiency" (poor reporting formatting) is, in reality, a strategic manifestation of professional territoriality. The shortcoming of the boundary object is not merely a design imperfection; it is an active mechanism

of boundary maintenance (Abbott, 1988) designed to prevent jurisdictional encroachment and solidify the "pré carré."

The breakdown of social exchange:

Furthermore, this boundary work actively degrades the social exchanges (Blau, 1964) required for innovation appropriation. The study highlights that trust is not a static attribute of the technology but a dynamic relational outcome. When boundary work prevents the delivery of an integrated, contextualized report, referring clinicians experience a breakdown in interprofessional reciprocity. This unfulfilled "unspecified obligation" drastically increases the cognitive cost of using the technology, driving the gatekeepers to rely on traditional, siloed imaging modalities where the social exchange remains predictable.

Ultimately, viewing our results through the lens of institutional theory (Reay & Hinings, 2009), our data illustrates a fundamental clash. The introduction of hybrid imaging demands a "logic of collaborative, integrated care", yet it crashes into the historically entrenched "logic of medical professionalism", which prioritizes siloed expertise. This statement claims that to successfully manage innovation in healthcare, managers must stop treating hybrid technologies as simple hardware upgrades and instead manage them as profound socio-organizational disruptions that require the active mediation of professional boundaries and interprofessional trust.

Resolving this contested adoption requires more than asking oncologists to simply change their routines to accommodate the constraint. Overcoming such a material constraint requires a "human-to-material imbrication" - where users' goals drive a change in the technology's material features. Altering the technology's material agency by engineering Structured Reporting (SR) should help to create a true boundary object, aligning the artifact's capabilities with the gatekeepers' clinical goals (Nobel et al., 2020).

6. Managerial implications and strategies

To optimize the diffusion of hybrid innovations and address the structural barriers identified, managers must implement targeted socio-organizational strategies (Greenhalgh et al., 2004) The following strategies (Table 2) translate our theoretical diagnosis into actionable management frameworks, demonstrating how structural constraints can be overcome through strategic intervention.

Re-engineering the report as a pragmatic boundary object:

Reports should be reconceptualized as expert consultations using structured, synoptic, and image-rich formats (Image-Rich Radiology Reports - IRRR) to reduce the interpretive burden (complexity) on referrers (Patel et al., 2017)(Iyer et al., 2010). Since many clinicians only read the conclusion, this section must be critical and address the specific clinical question asked. Theoretically, implementing SR forces the creation of a true pragmatic boundary object". By mandating a format that synthesizes both metabolic and anatomical data, management compels the different specialties to transform their localized knowledge into a shared artifact, thereby resolving the technology's incompatibility with the oncologists' decision-making routines.

Demonstrating hybrid expertise to bridge jurisdictions:

NM must deepen radiological training and prioritize collaborative bridges (e.g., joint case reviews) with radiology while respecting legal and professional boundaries. This strategy actively addresses the "skill gap" and mitigates defensive boundary work (Abbott, 1988) by fostering cross-disciplinary legitimacy rather than territorial threat.

Proactive collaboration and the management of rivalry:

Consistent participation in Multidisciplinary Team Meetings (MDT) and direct communication regarding critical findings are essential. Drawing on (Reay & Hinings, 2009) concept of managing rivalry, we propose that these MDT meetings serve as the critical organizational arenas where micro-level pragmatic collaboration occurs. Even while the macro-level logics of the professions remain in conflict, MDTs provide a structured space for actors to fulfill "unspecified obligations" (Blau, 1964). It is within these regular, task-focused meetings that interprofessional trust and reciprocity are dynamically rebuilt.

Preparing for Radioligand Therapy (RLT):

The lessons from PET-CT must be applied to the RLT transition, ensuring NM evolves into a theranostic specialty through co-defined care pathways with oncologists. As NM transitions toward a more direct therapeutic role through RLT, departments must adapt by developing comprehensive patient management protocols that include toxicity monitoring and long-term follow-up care. This shift represents a fundamental reconfiguration of the specialty's identity, moving from a transactional diagnostic service to a collaborative clinical partnership. If the socio-relational frictions and boundary disputes observed with PET-CT are not resolved, the much more

complex assimilation of RLT - which completely disrupts the traditional boundaries between diagnosis and therapy - will face insurmountable structural resistance.

Table 2: managerial strategies to address the challenge of PET-CT adoption in oncology

Managerial objective	Oncologist expectation / requirement	Current barrier	Proposed strategy	Intended outcome
Re-engineering reports as decision-making tools	Comprehensive synthesis of metabolic and anatomical findings.	Fragmented information increasing perceived complexity for referrers.	Implement Structured Reporting (SR) and Image-Rich Radiology Reports (IRRR).	Establish the report as a true "boundary object" that enhances clinical utility and restores trust.
Overcoming professional silos & hybrid skill gaps	A true "one-stop-shop" interpretation.	"Boundary work" between Radiology and NM; perceived lack of CT proficiency.	Foster cross-disciplinary education, joint case reviews, and co-construction of integrated reports.	Demonstrate hybrid expertise and bridge professional jurisdictions.
Strengthening proactive collaboration	Contextualized interpretations and high responsiveness.	Organizational/geographical distance and lack of reciprocity.	Mandate NM participation in Multidisciplinary Team (MDT) meetings and direct communication.	Transition from a transactional service to a collaborative partnership.
Strategic preparation for Radioligand Therapy (RLT)	Guidance on therapy selection and long-term follow-up.	Traditional perception of NM as purely diagnostic.	Develop patient management protocols and co-defined care pathways with oncology.	Reconfigure NM as a theranostic specialty and indispensable therapeutic partner.

7. Conclusions, limitations and future research agenda

This study demonstrates that the integration of PET-CT is a complex socio-technical process where utility is actively co-constructed by gatekeeper clinicians, conditioned heavily by the historical separation of nuclear medicine and radiology. The limitations of the medical report to act as an effective boundary object, in conjunction with active boundary work, severely hinders optimal diffusion.

Limitations:

While this study achieves analytical generalization regarding socio-organizational mechanisms ("skill gap", "boundary work"), its statistical generalizability is limited by the small sample size (n=13) across only two centers, the underrepresentation of radiologists, and the absence of onco-hematologists.

Agenda for future research:

To build upon these findings and extend the literature on healthcare innovation management, we propose the following detailed research agenda:

- Quantitative validation of boundary effects: future studies should incorporate national, quantitative PET-CT utilization data to bridge our qualitative insights on professional silos with broader macro-level activity trends.
- Longitudinal study of the RLT transition: As NM evolves into a theranostic specialty, longitudinal research (potentially applying Lewin's change models) should track how professional identities, interprofessional trust, and boundary work adapt over time.
- Action-research on boundary objects: action-research should be conducted alongside clinical teams to iteratively design, implement, and test structured, Image-Rich Radiology Reports (IRRR). This will directly measure the impact of new boundary objects on reducing perceived "complexity" for referring oncologists.
- Cross-national comparisons: comparative international studies (e.g., contrasting the French siloed system with fully integrated hybrid departments in other nations) are needed to clarify how varying regulatory and educational environments affect the compatibility and diffusion of hybrid technologies.

By translating these social sciences insights into actionable strategies, healthcare systems can successfully navigate professional boundaries and realize the full potential of complex medical imaging innovations.

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