Observed Versus Expected Use of Diagnostic Imaging and Radiotherapy in Prostate Cancer: A Population-Based Framework for Healthcare Planning

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Article

Observed Versus Expected Use of Diagnostic Imaging and Radiotherapy in Prostate Cancer: A Population-Based Framework for Healthcare Planning

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Highlights

What are the main findings?

- A population-based framework integrating cancer registry data, administrative databases, and literature evidence was developed to estimate diagnostic imaging and radiotherapy needs in prostate cancer.
- In the Lazio Region (central Italy), expected utilization of key services consistently exceeded observed utilization, indicating potential gaps in service provision.

What are the implications of the main findings?

- Comparing expected and observed service use can support healthcare planning by identifying mismatches between clinical needs and available resources.
- The proposed framework is reproducible and adaptable to other oncological pathways and healthcare systems to support healthcare planning.

Abstract

Background/Objectives: Accurate estimation of healthcare service requirements is essential for planning oncological care pathways, particularly in resource-constrained settings. We developed and applied a population-based methodological framework to estimate observed and expected utilization of diagnostic imaging and radiotherapy along the prostate cancer care pathway in the Lazio Region (central Italy). **Methods**: The cohort study included all incident cases recorded in the Regional Cancer Registry in 2019 (n = 3047) and estimate in 2022 (n = 3254), through the integration of cancer registry data and health information systems. For each cohort, 16 indicators (magnetic resonance imaging, biopsy, metastatic staging imaging, radiotherapy) were calculated, estimating usage proportions, median delivery times, and stratifying by age class. The expected requirement was estimated through four rapid literature reviews. **Results**: Expected utilization was consistently higher than observed utilization. Radiotherapy was expected in approximately 40% of patients, whereas the observed utilization was 23.00% of cases (95% CI 21.48–24.61) in 2019 and 22.52% of cases (95% CI 21.07–24.03) in 2022. The provision of imaging for metastatic staging—40.85% (95% CI 39.06–42.67) in 2019 and 34.84% (95% CI 33.19–36.53) in 2022—was lower than the expected value of 50%. Differences in utilization patterns by age group and timing of service delivery were observed. **Conclusions**: Overall, a gap was identified between expected and delivered care, suggesting the need to review the provision of diagnostic and therapeutic services. This reproducible and adaptable methodology can

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be applied to other care pathways and healthcare settings, thereby supporting strategic resource allocation and continuous monitoring.

Keywords: prostate cancer; healthcare planning; cancer registry; radiotherapy utilization; diagnostic imaging; care pathways; demand estimation; health services research

1. Introduction

The assessment of healthcare service requirements represents a major public health challenge, particularly in contexts characterized by constrained resources and growing population health needs. Such analyses are essential to inform healthcare planning and to ensure alignment between evidence-based clinical guidelines and their implementation within specific organizational frameworks. Various methodological approaches have been developed to address this objective, and several authors have emphasized that different methods may be more appropriate depending on the purpose and setting of the analysis [1,2]. Overall, existing literature has primarily focused on estimating requirements for the healthcare workforce rather than for healthcare services themselves, with the aim of quantifying total resource needs in terms of physicians and nurses or concentrating on single components of care—such as radiotherapy—to estimate changes or trends within a defined geographical area [3–5]. By contrast, relatively few studies have addressed the entire care process of a specific disease, an approach that is particularly relevant for the effective implementation of new clinical pathways, including those developed for specific cancers, such as prostate cancer.

Within this broader context, integrated care pathways for prostate cancer represent a paradigmatic example. Prostate cancer is among the most common malignancies in men worldwide and is characterized by heterogeneous clinical trajectories, requiring tailored diagnostic strategies and treatment modalities.

In the Lazio Region (central Italy), within the framework of the Regional Oncological Network, a new clinical pathway for patients with suspected prostate cancer has been developed. Designed to cover the full continuum of care - from diagnosis to treatment and follow-up - and aligned with current clinical guidelines, the pathway specifies the appropriate diagnostic examinations and therapeutic interventions for each disease stage at diagnosis. Before its implementation, estimating the required volume of diagnostic imaging procedures, including magnetic resonance imaging (MRI), scintigraphy, computed tomography, as well as radiotherapy (RT) services, is essential to ensure adequate resource allocation.

To achieve this aim, based on existing models in the literature, two main approaches to assessing healthcare service requirements can be distinguished: utilization-based and need-based. Utilization or demand-based methodologies rely on current patterns of health service use, as observed in healthcare data sources, whereas need-based approaches estimate resource requirements on the basis of epidemiological expectations, such as disease incidence and stage distribution. Integrating these two perspectives offers a powerful framework for identifying gaps and supporting data-informed healthcare planning.

Within this context, the Department of Epidemiology of Lazio Region Health Service was mandated to estimate resource requirements for the new prostate cancer clinical pathway, to support improved resource allocation across the Local Health Authorities of the Region. This paper aims to describe and apply a population-based methodological framework used to estimate healthcare services considered most relevant for patient management, specifically diagnostic imaging and radiotherapy for incident prostate cancer cases. The study endpoints included the analysis of observed utilization through the use of available population-based and administrative data and the estimation of expected needs based on evidence from the scientific literature and recommendations from clinical guidelines, with a specific application to the regional context. The gap between observed and expected utilization of healthcare services was subsequently examined. Although applied to a

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large Italian region, the proposed approach is designed to be transferable to other oncological pathways and healthcare settings, providing a scalable tool.

2. Materials and Methods

2.1. Rapid Reviews

To estimate population needs in terms of diagnostic procedures and radiotherapy, we conducted four rapid reviews to assess the expected demand in the Italian context based on the available literature. Rapid reviews are commonly used to synthesize evidence within a specific field and context in order to inform policymakers within a short time frame [6].

Specifically, we aimed to estimate: (1) the proportion of patients with MRI performed for suspected prostate cancer who subsequently underwent prostate biopsy; (2) the proportion of biopsies resulting in a diagnosis of prostate cancer; (3) the distribution of newly diagnosed prostate cancer cases according to D'Amico risk categories (low, intermediate, and high); and (4) the proportion of newly diagnosed patients who underwent radiotherapy. The D'Amico risk classification was selected because it is the criteria adopted by the Lazio Region clinical pathway to identify patients eligible for further diagnostic imaging procedures (e.g., whole-body CT). Sensitivity analyses were also conducted using alternative risk classification systems.

For each objective, a rapid review was conducted using MEDLINE (via PubMed). An approach based on the population, intervention, comparison and outcome (PICO) method was used, and four different search strings were developed (See Supplementary Table S1). Studies were considered eligible if they were conducted in Italy and included either individuals with suspected prostate cancer (for estimates related to MRI and biopsy outcomes) or patients with a diagnosis of prostate cancer (for estimates related to D'Amico risk categories and radiotherapy use). Articles were included regardless of their primary study objective, considering sufficient that the outcome of interest was reported or could be calculated.

To obtain estimates relevant to current practice, we limited inclusion to studies published between 1 January 2016 and 28 February 2026. Studies were excluded if they focused on excessively narrow subpopulations of patients with suspected prostate cancer (e.g., only individuals with a single MRI lesion or with two or more lesions; only patients with positive or negative digital rectal examination), as such restrictions would limit the generalizability of the estimates to the broader population.

Data were extracted using a standardized form capturing bibliographic information and outcomes of interest. To estimate expected demand, medians and interquartile ranges (IQRs) were calculated for each parameter. When too few studies were available, individual study estimates were reported.

2.2. Data Sources

Prostate cancer incidence data for the Lazio Region were obtained from the Lazio Region Cancer Registry (LRCR), a population-based registry that identifies incident cancer cases through systematic individual-level record linkage across multiple Healthcare Information System (HIS) databases, as previously described in detail [7]. Briefly, the LRCR integrates the traditional data sources commonly used by cancer registries, including Hospital Discharge Records (HDRs), pathology reports, death certificates, and ancillary datasets. All residents of the Lazio Region are assigned a unique encrypted personal identifier, which enables accurate linkage across data sources and prevents double counting. The LRCR manages approximately 35,000 new cancer cases each year and produces both provisional incidence estimates based on up-to-date administrative HIS data and fully consolidated incidence data validated by trained registrars; consolidated data for all cancer sites are currently available up to 2019.

For the purposes of this study, we used consolidated prostate cancer incidence data for 2019 and incidence estimates for 2022. All prostate cancer cases (ICD-O-3 topography code C61) were extracted

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from the LRCR database. To ensure data accuracy within the regional health context, patients not residing in the Lazio Region at the time of diagnosis were excluded using the Healthcare Assistance Registry. Individual-level record linkage was performed to integrate information across data sources including the Outpatient Specialist Care Information System (OSCIS) and HDRs. Information on vital status was obtained from HDRs, the Health Emergency Information System, Healthcare Assistance Registry and death certificates (available only for the 2019 cohort).

2.3. Study Design and Population

A population-based cohort study was conducted to analyze the observed utilization of healthcare services among patients with incident prostate cancer. Sixteen indicators were defined for each cohort to capture the utilization of selected diagnostic and therapeutic services. All patients with an incident diagnosis of prostate cancer recorded in the LRCR in 2019 or estimated in 2022 were included. The date of cancer diagnosis was defined as the index date. Patients were followed to assess the utilization of healthcare services relevant to prostate cancer management. Information on diagnostic and therapeutic healthcare services was obtained through record linkage with the HDRs and the OSCIS.

2.4. Outcomes

The study evaluated the observed utilization of diagnostic and therapeutic services, including prostate MRI, biopsy, surgical treatment, imaging for metastatic staging (scintigraphy, whole-body CT, PSMA PET/CT) and radiotherapy. Radiotherapy was analyzed in three ways: any radiotherapy, adjuvant radiotherapy (following surgery), and radiotherapy delivered in the absence of surgical intervention. For each cohort, a set of indicators was calculated (See Supplementary Table S2). For each service, the proportion of patients receiving the procedure and the median time from diagnosis - or surgery, when applicable - to service delivery were estimated. Healthcare services were identified within predefined time windows relative to the index date or the date of surgery (See Supplementary Table S3).

2.5. Statistical Analysis

Descriptive analyses were performed to evaluate the observed utilization for each healthcare service. Results were reported as proportions and median times to service utilization. Ninety-five percent Confidence Intervals (95% CI) were calculated using the Wilson score method. Analyses were conducted separately for the 2019 and 2022 cohorts and stratified by age group where appropriate.

To account for competing risks, a one-year mortality follow-up was conducted for all cases. Specifically, patients who died before the end of an indicator-specific time window were excluded from the corresponding analysis to avoid underestimating service utilization.

Statistical analyses were performed using SAS Enterprise Guide, version 8.3.

3. Results

Flow diagrams for each rapid review are provided in the Supplementary Materials S4-7. The literature searches identified 422, 216, 171, and 532 records for the reviews, estimating the proportions related to MRI findings, prostate biopsy outcomes, D'Amico risk categories, and radiotherapy use, respectively. Following the screening process, 6, 35, 7, and 3 studies were included for the respective reviews. In addition, some studies retrieved for one review were also included in another review when relevant to a different objective.

Extracted estimates are summarized in Tables S8–S11. Overall, substantial between-study variability was observed, particularly for the proportion of patients with lesions detected on MRI. The median proportion of positive MRI findings (defined as a PI-RADS score ≥ 3, generally considered an indication for biopsy) was 70.0%, with an IQR of 52.5-76.6%. The median proportion of positive biopsies was 60.4% (IQR 52.2–64.8%) for prostate cancer overall and 39.0% (IQR 34.8–

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48.5%) for clinically significant prostate cancer. Regarding risk stratification, the median distribution according to D'Amico classification was approximately 24.0% (IQR 22.6–33.2%) for low-risk, 49.5% (IQR 45.1–52.8%) for intermediate-risk, and 24.1% (IQR 17.1–26.2%) for high-risk disease. Only one study further distinguished intermediate-risk patients, reporting 16.0% with favorable and 30.4% with unfavorable intermediate-risk disease. Sensitivity analyses incorporating alternative risk classification systems yielded minimal differences. Among the three studies reporting radiotherapy use, one study, including all newly diagnosed prostate cancer cases, found that approximately one-third of patients underwent radiotherapy. In contrast, two studies restricted to patients without metastases or with localized disease reported higher proportions, at approximately 40%. Additionally, one of them reported an 11.7% increase in radiotherapy use following radical prostatectomy; this finding is consistent with results from another study not included in the review, which reported a corresponding estimate of 14.8%.

A total of 3047 patients were included in the 2019 cohort and 3254 in the 2022 cohort. Table 1 presents the age characteristics of the two cohorts, while Figure 1 shows the percentage of patients with at least a diagnostic (biopsy, MRI and imaging for metastatic staging) or therapeutic (surgery and RT) procedures within specified time windows for the 2019 and 2022 cohorts.

Table 1. Age distribution of patients in the 2019 and 2022 cohorts.

Cohort	2019 (N=3047)	2022 (N=3254)
	n (%)	
20-54	132 (4.3)	126 (3.9)
55-64	649 (21.3)	748 (23.0)
65-74	1,239 (40.7)	1,477 (45.4)
75-84	839 (27.5)	768 (23.6)
85+	188 (6.2)	135 (4.1)
Median (IQR)	71.15 (12.5)	70.36 (11.2)

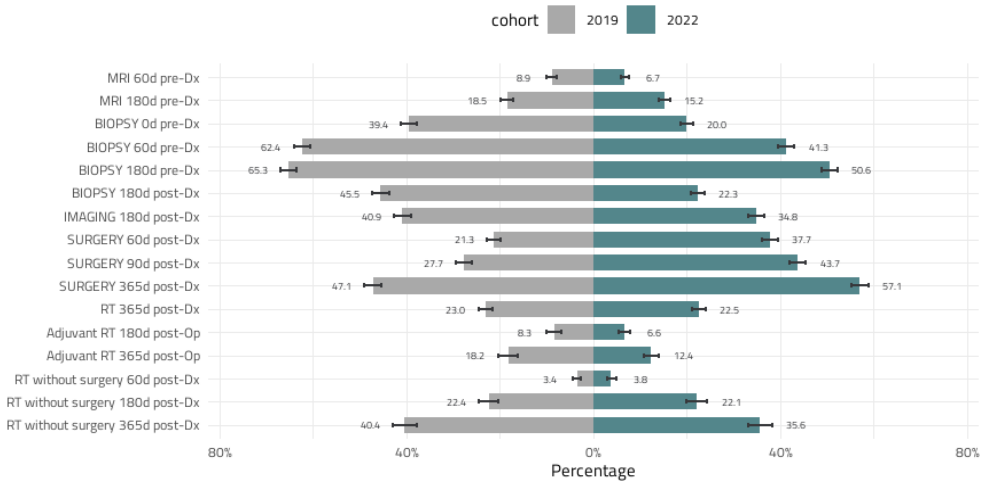

Figure 1. Diagnostic and treatment pathways for the 2019 and 2022 cohorts. This figure presents the percentage of patients with at least a diagnostic (biopsy, MRI and imaging for metastatic staging) or therapeutic (surgery and RT) procedure within specified time windows (e.g., 60 days pre- or post-diagnosis/surgery) for the 2019 and 2022 cohorts. .

With respect to diagnostic procedures, both cohorts showed similar proportions of patients undergoing MRI within 60 or 180 days before diagnosis. In the 2019 cohort, 65.28% (95% CI 63.57–

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66.95) of patients underwent biopsy, whereas this proportion was lower in the 2022 cohort. When considering the 180 days after diagnosis, 40.85% (95% CI 39.06–42.67) of patients underwent imaging for metastatic evaluation in the 2019 cohort and 34.84% (95% CI 33.19–36.53) in the 2022 cohort.

Regarding therapeutic interventions, notable differences emerged between cohorts: 21.28% (95% CI 19.82–22.80) of patients in the 2019 cohort underwent surgery within 60 days of diagnosis, compared with 37.72% (95% CI 36.06–39.42) in the 2022 cohort. Radiotherapy utilization was consistent across cohorts and was higher among patients who did not undergo surgery.

Stratified analyses by age group revealed substantial differences in treatment patterns (see Supplementary Table S12, Figures S13 and S14). Younger patients were more likely to undergo surgery, whereas older patients more frequently received radiotherapy. Patients aged 85 years and older consistently showed lower treatment proportions, indicating more conservative management strategies in the oldest age groups. Figure 2 presents estimates of expected healthcare service needs. Based on the literature and considering the 3,254 incident cases recorded in the Lazio Region in 2022, the estimated need corresponds to 5,423 prostate biopsies and 7,747 prostate MRI examinations. Expected pre-diagnostic volumes refer to men investigated for suspected prostate cancer (not only incident cases).

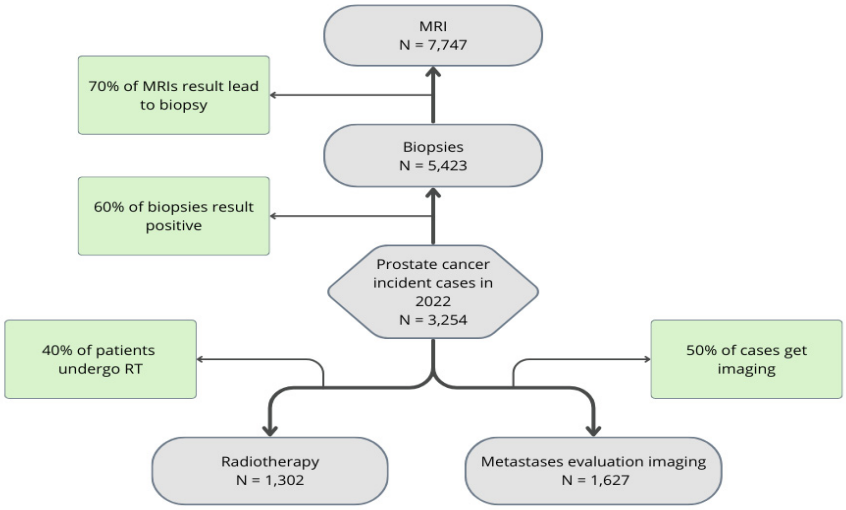

Figure 2. Flowchart of the diagnostic and treatment pathways for incident prostate cancer cases (2022 cohort). The flowchart illustrates the sequential steps in the diagnostic and therapeutic pathway for prostate cancer incident cases in 2022 and provides procedural estimates based on literature.

Post-diagnosis, the literature suggests that approximately 40% of patients undergo radiotherapy, corresponding to an estimated need of 1,302 radiotherapy treatments. This estimate exceeds observed utilization, as radiotherapy was delivered in 23.00% (95% CI 21.48–24.61) of cases in the 2019 cohort and in 22.52% (95% CI 21.07–24.03) of cases in the 2022 cohort (Figures 1 and 3). For imaging aimed at metastatic staging, reported utilization is approximately 50%, based on the assumption that imaging was indicated in all high-risk patients and in those with unfavorable intermediate-risk disease, who were assumed to represent approximately half of the intermediate-risk population. Although the observed proportions were lower (Figure 1), the estimated need corresponds to 1,627 procedures (Figure 3). Overall, expected needs consistently exceeded observed utilization for several key services, particularly radiotherapy and staging imaging (Figure 3).

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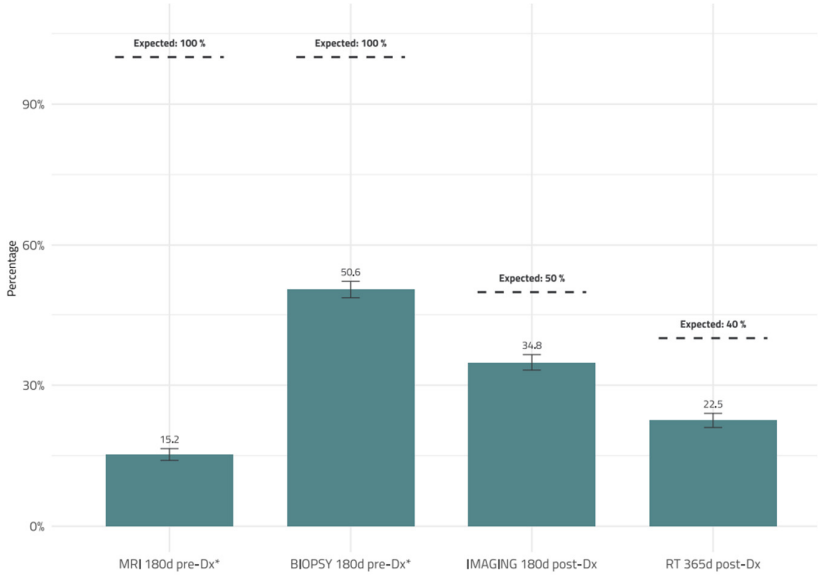

Figure 3. Comparison between expected and observed values. * Expected pre-diagnostic volumes refer to men investigated for suspected prostate cancer, not only incident cases.

This analytical approach, based on regional data, can be readily extended to individual Local Health Authorities or Districts by stratifying incident cases according to patients' place of residence at diagnosis.

4. Discussion

This study provides an integrated assessment of observed utilization and expected need for diagnostic and therapeutic services along the prostate cancer care pathway in the Lazio Region. By analyzing incident cohorts from 2019 and 2022, the findings highlight relevant discrepancies between real-world service use and needs estimated on the basis of epidemiological evidence and clinical guideline recommendations. While the utilization of some diagnostic procedures, such as prostate magnetic resonance imaging and radiotherapy, showed overall consistency across cohorts, substantial differences emerged in the timing and uptake of surgical interventions. Need-based estimates consistently exceeded observed utilization, particularly for radiotherapy and imaging procedures aimed at metastatic staging, suggesting potential underuse of key services within the regional healthcare system. Differences between observed and expected utilization should not be interpreted as indicators of inappropriate care per se, but rather as signals of contextual or data-related constraints, likely reflecting organizational factors, evolving clinical recommendations, and limitations inherent in available data sources.

With regard to the rapid review addressing the proportion of patients undergoing magnetic resonance imaging for suspected prostate cancer who subsequently received a prostate biopsy, a substantial variability was observed across the included studies. Nevertheless, the median value was consistent with that reported in a large international multicenter study [8]. Concerning the proportion of biopsies resulting in a diagnosis of prostate cancer, most of the included studies showed largely consistent findings. However, a marked difference was observed between the detection rate referring to all malignant tumors—which was considered for the estimates presented in the present study—and that limited to clinically significant prostate cancer. This distinction is particularly relevant, as it may have a substantial impact on the estimation of healthcare needs. In the rapid review on the distribution of newly diagnosed prostate cancer cases according to D'Amico risk categories, a high degree of heterogeneity was identified among the included studies, mainly due to differences in cohort selection and in the type of therapy delivered. Despite this heterogeneity, the median values

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and interquartile ranges were consistent with those reported in studies adopting alternative risk stratification systems [9–14]. Finally, the limited number of studies included in the rapid review on the proportion of newly diagnosed patients who underwent radiotherapy, despite the consistency of their findings, may reflect a potential selection bias related to the inclusion criteria, search strategy, or the methodological constraints inherent to rapid review approaches.

In addition, selected indicators were calculated using different temporal windows in order to explore the timeliness of healthcare delivery along the prostate cancer care pathway. Timeliness represents a key quality dimension of cancer care and provides complementary information on service functioning beyond overall utilization rates. In the present analysis, these indicators suggest that, in general, the time elapsed between key steps of the diagnostic–therapeutic process and the delivery of healthcare services was longer than that recommended by international clinical guidelines. According to such guidelines, the clinical staging phase should be completed within approximately 30–45 days from the initial urological consultation, while definitive treatments such as surgical intervention and radiotherapy are generally expected to be initiated within 60 days from diagnosis or clinical decision-making. The use of multiple observation windows in this study was therefore intended to capture not only whether services were delivered, but also the extent to which their timing aligned with guideline-based standards of care, providing additional insights into potential organizational delays and the overall performance of the regional prostate cancer care pathway [15–17].

Overall, the results underscore the value of a methodology that entails the integration of population-based cancer registry data, healthcare administrative flows, and evidence from the literature to support healthcare planning and to inform the implementation and continuous monitoring of comprehensive oncological clinical pathways.

4.1. Comparison Between Observed and Expected Utilization of Healthcare Services

The comparison between observed and expected utilization revealed several relevant discrepancies across the diagnostic, staging, and therapeutic phases of the prostate cancer care pathway. These discrepancies can largely be explained by temporal, organizational, and data-related factors.

With regard to diagnostic imaging, the proportion of patients undergoing prostate MRI within the Regional Health Service was consistent across the two incident cohorts but substantially lower than expected based on published evidence. This finding is consistent with the timing of guideline updates: during the study period (2019–2022), multiparametric prostate MRI was formally incorporated into the updated regional diagnostic pathway only after the study period (2025), despite its growing clinical relevance documented in the literature [18,19]. Indeed, several studies have demonstrated the increasing role of MRI in improving the detection of clinically significant prostate cancer and in guiding biopsy decisions, particularly in younger patients and in those with equivocal PSA findings [18,19]. The observed underutilization therefore likely reflects a lag between emerging clinical evidence and its formal adoption within regional organizational frameworks, a phenomenon commonly described in the implementation of diagnostic innovations in healthcare systems [15].

Differences observed in biopsy-related indicators between the two cohorts are plausibly attributable to differing degrees of data consolidation. In the 2022 cohort, incident cases were identified primarily through administrative healthcare databases, without systematic linkage to pathology records, which represent the main source for accurate incidence dating in population-based cancer registries. This approach likely resulted in delayed assignment of the incidence date, often coinciding with surgical intervention rather than histological diagnosis, leading to an apparent reduction in the proportion of biopsies captured within predefined time windows. Similar methodological challenges related to case ascertainment, incidence dating, and misclassification have been widely reported in population-based studies relying on administrative data sources for cancer surveillance [20,21].

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For staging imaging aimed at metastatic assessment, the observed proportions were lower than those expected based on clinical recommendations. International guidelines indicate that systemic staging examinations are required in a substantial proportion of newly diagnosed prostate cancer patients, particularly those with intermediate- to high-risk disease [16]. The discrepancies observed between cohorts—especially when narrower temporal windows around diagnosis were considered—further support the hypothesis that imprecision in incidence dating and incomplete capture of early diagnostic procedures play a relevant role, particularly in less consolidated datasets.

Regarding therapeutic interventions, the apparent underestimation of non-surgically treated patients in the 2022 cohort suggests incomplete capture of patients managed conservatively or treated exclusively with radiotherapy or systemic therapies, who may be less consistently recorded in hospital discharge databases. This issue is particularly relevant in prostate cancer, where treatment strategies vary widely according to clinical stage, risk stratification, patient age, and comorbidities, as documented in national observational studies [22,23]. As a consequence, administrative data may preferentially capture surgically treated patients, distorting the apparent distribution of care pathways. In addition, an updated linkage with pathology data could be used as a sensitivity analysis to evaluate the completeness and effectiveness of the monitoring system based on current healthcare administrative databases in comprehensively identifying incident cases.

Radiotherapy-related indicators were generally consistent between cohorts and aligned with evidence from national and international studies, which identify radiotherapy as a primary or complementary treatment option in a substantial proportion of patients, particularly those not undergoing surgery or those with biochemical recurrence or metastatic disease [23,24]. The higher use of radiotherapy among non-operated patients observed in this study is therefore expected and consistent with current clinical guidelines.

Nevertheless, it is plausible that the COVID-19 emergency during 2020–2022 influenced adherence to oncology care pathways and the timeliness of diagnostic and therapeutic procedures, potentially contributing to the observed gap between expected and observed service utilization and, more broadly, to disruptions in case ascertainment [25].

4.2. Comparison with Previous Studies and Implications for Healthcare Planning

Although several studies have described the incidence, prevalence, and treatment patterns of prostate cancer in Italy [26–29], to date, few studies have attempted to translate epidemiological data into explicit estimates of healthcare service demand across the care pathway [30–32]. In this respect, the present study contributes novel evidence not only by quantifying potential gaps between expected and observed service utilization, but also by proposing a structured, population-based and guideline-informed methodological framework for demand estimation, consistent with approaches previously developed for oncology service planning and radiotherapy resource allocation [30–32].

The estimated demand for diagnostic imaging and radiotherapy exceeded observed service utilization, particularly for radiotherapy. Similar gaps between optimal and actual radiotherapy utilization have been reported in several European countries and are commonly interpreted as indicators of potential under-provision, organizational constraints, or barriers to access [33–35].

From a healthcare governance perspective, these findings highlight the value of demand estimation models as decision-support tools to identify mismatches between clinical needs and available resources and to inform evidence-based planning and prioritization processes, as previously emphasized in health services research [33–36].

4.3. Strengths and Limitations

The main strength of this study lies in the development and application of a structured, transparent, and reproducible methodology for estimating healthcare service utilization in oncology, grounded in real-world population data and aligned with clinical guidelines and scientific literature. While prostate cancer in the Lazio region represents the application context of this study, the methodological approach was explicitly conceived to be transferable and adaptable to other

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oncological pathways and healthcare settings, in line with established models for cancer service planning and resource estimation [33–35].

From a broader perspective, this study underscores the importance of embedding demand estimation exercises within the continuous monitoring and revision of clinical pathways. As clinical recommendations evolve and healthcare systems adapt, dynamic and data-informed models are required to ensure alignment between clinical needs, organizational capacity, and policy objectives. In this context, the use of the Lazio Cancer Registry ensured accurate case definition and incidence dating for the consolidated cohort. Its integration with administrative healthcare flows and evidence from the literature represents a pragmatic and robust foundation for informed decision-making.

However, several limitations should be acknowledged. The rapid evolution of clinical recommendations—particularly with regard to radiotherapy indications and advanced imaging techniques—poses challenges to the use of published literature as a stable reference for expected demand. Continuous interaction with clinical experts is therefore essential to validate and periodically update the assumptions underlying the estimates.

Reliance on historical data limits the ability to fully capture recent organizational changes, such as the formal introduction of prostate MRI into the updated regional clinical pathway. As healthcare systems evolve rapidly, historical utilization patterns may only partially reflect current and future needs. Nonetheless, population-based cancer registries remain a cornerstone of healthcare planning, offering comprehensive and reliable data that can be systematically updated over time.

The potential lack of information on services delivered in the private healthcare sector (i.e., outside the regional public healthcare system) may lead to an underestimation of service volumes, particularly for diagnostic imaging. However, its overall impact on estimated service utilization is expected to be modest within the regional healthcare context. This assumption is supported by the highly specialized and technology-intensive nature of advanced oncological imaging and radiotherapy services, which are predominantly delivered within accredited public or network-affiliated centres, and by the substantial costs associated with these procedures, which may reduce their uptake outside the regional public healthcare system [31,35].

Limitations in procedural coding within administrative databases hinder the precise identification of site-specific imaging and radiotherapy indications, a well-recognized issue in health services research that warrants further standardization efforts.

Finally, this analysis did not explicitly account for patients with disease recurrence or for the chronic clinical course that prostate cancer may assume in a subset of patients, potentially leading to sustained demand for diagnostic imaging and radiotherapy services over time [37].

5. Conclusions

This This study demonstrated how population-based data, administrative healthcare flows, and evidence from the literature can be systematically integrated to estimate the utilization of diagnostic imaging and radiotherapy services within an oncological care pathway. Beyond the specific case of prostate cancer in the Lazio region, the primary contribution of this work lies in the development of a flexible, reproducible, and scalable methodological framework for healthcare service demand estimation.

By building on consolidated approaches to cancer service planning and demand modelling, the proposed framework enables a structured comparison between observed and expected service utilization, thereby supporting evidence-informed decision-making at both regional and local levels. Furthermore, the systematic analysis of pathway-related critical issues offers policymakers a valuable opportunity to refine care networks, optimize resource allocation, and improve equity and quality of access to oncological services.

Although applied to prostate cancer, this pathway-based approach is inherently transferable and can be adapted to other oncological conditions characterized by complex diagnostic and therapeutic trajectories, providing healthcare planners with a pragmatic tool to anticipate service needs, identify

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gaps between demand and provision, and support strategic planning within regional and national cancer care systems.

Supplementary Materials: The following supporting information can be downloaded at: Preprints.org, Table S1: the research strings.; Table S2: outcomes described and defined according to the ICD-9-CM procedure codes (primary or secondary) for the HDR and the Italian nomenclature of outpatient specialist assistance for the OSCIS; Table S3: the observation windows related to each outcome; Figure S4: PRISMA 2020 flow diagram of rapid review n. 1) the proportion of patients with MRI performed for suspected prostate cancer who subsequently underwent prostate biopsy; Figure S5: PRISMA 2020 flow diagram of rapid review n. 2) the proportion of biopsies resulting in a diagnosis of prostate cancer; Figure S6: PRISMA 2020 flow diagram of rapid review n. 3) the distribution of newly diagnosed prostate cancer cases according to D'Amico risk categories (low, intermediate, and high); Figure S7: PRISMA 2020 flow diagram of rapid review n. 4) the proportion of newly diagnosed patients who underwent radiotherapy; Table S8: extracted estimates of rapid review n. 1) the proportion of patients with MRI performed for suspected prostate cancer who subsequently underwent prostate biopsy; Table S9: extracted estimates of rapid review n. 2) the proportion of biopsies resulting in a diagnosis of prostate cancer; Table S10: extracted estimates of rapid review n. 3) the distribution of newly diagnosed prostate cancer cases according to D'Amico risk categories (low, intermediate, and high); Table S11: extracted estimates of rapid review n. 4) the proportion of newly diagnosed patients who underwent radiotherapy; Table S12: diagnostic and treatment pathways of the 2019 and 2022 cohorts, stratified by age class. Median values are expressed in days; Figure S13: surgical treatment within 365 days post-diagnosis, stratified by age class in the two cohorts; Figure S14. radiotherapy within 365 days post-diagnosis, stratified by age class in the two cohorts.

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Data Availability Statement: All relevant data are within the paper and its Supporting Information files. Data related to the findings reported in our manuscript are available at an aggregated level to all interested researchers upon request because of stringent legal restrictions regarding privacy policy on personal information in Italy (European legislative decree on privacy policy 2016/679). For these reasons, our dataset cannot be made available in a public repository. Although data are appropriately anonymized, we are not authorized to share any dataset, because data are restricted by the Health Information System Unit, Directorate for Health and Social Care Integration of the Lazio Regional Health Service, Rome, Italy. All interested researchers, who meet the criteria for access to confidential data, can contact: Paola Michelozzi, Head of Department of Epidemiology of Lazio Regional Health Service, Rome, Italy, email: dipepi@deplazio.it.

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Abbreviations

The following abbreviations are used in this manuscript:

MRI	Magnetic Resonance Imaging
RT	Radiotherapy
IQR	Interquartile Range
LRCR	Lazio Region Cancer Registry
HIS	Healthcare Information System
HDR	Hospital Discharge Records
OSCIS	Outpatient Specialist Care Information System
95% CI	Ninety-five percent confidence intervals

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