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Original Article

Histopathological Patterns of Prostate Carcinoma in Needle Biopsy: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: Prostate carcinoma is one of the most common malignancies among men worldwide. Needle biopsy remains the gold standard diagnostic method for histopathological confirmation. Different architectural patterns and histological variants observed in biopsy specimens have important prognostic implications. This systematic review and meta-analysis aimed to evaluate the spectrum and prevalence of histopathological patterns of prostate carcinoma detected in needle biopsy specimens.

Methods: A systematic search of PubMed, Scopus, Web of Science, and Google Scholar was conducted for studies published between 2000 and 2025 reporting histopathological patterns of prostate carcinoma in needle biopsy samples. Studies reporting Gleason grading, histological variants, and architectural patterns were included. Data were extracted independently by two reviewers. A random-effects meta-analysis was performed to estimate pooled prevalence of major histopathological patterns.

Results: A total of 24 studies involving 9,842 prostate biopsy specimens were included. Conventional acinar adenocarcinoma was the most common histological subtype with a pooled prevalence of 92.6% (95% CI: 88.4–95.1). Other variants included foamy gland carcinoma (4.3%), ductal adenocarcinoma (1.8%), atrophic carcinoma (0.9%), and mucinous adenocarcinoma (0.4%). The most frequent Gleason pattern identified was pattern 3 followed by pattern 4. Gleason score 7 was the most commonly reported composite score across studies. High-grade features such as cribriform and glomeruloid patterns were associated with higher Gleason scores and aggressive clinical behavior.

Keywords: *Prostate carcinoma, needle biopsy, histopathology, Gleason grading, systematic review, meta-analysis.*

INTRODUCTION

Prostate cancer is the second most frequently diagnosed cancer among men worldwide and represents a significant global health burden [1]. The incidence of prostate carcinoma has increased steadily over the past few decades due to improved screening methods and increased life expectancy [2].

Histopathological examination of prostate tissue obtained through transrectal or transperineal needle biopsy remains the gold standard for diagnosing prostate carcinoma [3]. Needle biopsy allows pathologists to evaluate tumor architecture, cellular morphology, and histological patterns that determine tumor aggressiveness and guide clinical management [4].

The Gleason grading system, introduced by Donald Gleason in the 1960s, remains the cornerstone for grading prostate carcinoma [5]. This system evaluates glandular architecture and assigns a score based on the two most predominant

histological patterns observed in the tumor [6]. Higher Gleason scores are associated with poorly differentiated tumors and worse clinical outcomes [7].

The majority of prostate cancers diagnosed on biopsy are classified as conventional acinar adenocarcinoma, which accounts for more than 90% of cases [8]. However, several histological variants have been described, including ductal adenocarcinoma, foamy gland carcinoma, mucinous carcinoma, signet-ring carcinoma, and atrophic carcinoma [9]. These variants may have unique morphological features and distinct clinical implications.

Recent studies have also emphasized the prognostic importance of specific architectural patterns such as cribriform growth and intraductal carcinoma, which are associated with aggressive disease and increased risk of metastasis [10].

Although numerous individual studies have reported histopathological findings of prostate carcinoma in needle biopsy specimens, there is limited consolidated evidence summarizing these patterns across different populations. Therefore, the present systematic review and meta-analysis aimed to evaluate the prevalence and distribution of histopathological patterns of prostate carcinoma detected in needle biopsy specimens.

MATERIALS AND METHODS

Study Design

This systematic review and meta-analysis was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [11].

Search Strategy

A comprehensive literature search was performed in the following electronic databases:

- PubMed
- Scopus
- Web of Science
- Google Scholar

Studies published between January 2000 and December 2025 were considered. The search strategy included combinations of the following keywords:

- “Prostate carcinoma”
- “Prostate needle biopsy”
- “Histopathological patterns”
- “Gleason score”
- “Prostate adenocarcinoma variants”

Boolean operators (AND/OR) were applied to combine search terms and retrieve relevant studies [12].

Inclusion Criteria

Studies were included if they:

1. Reported histopathological findings in prostate needle biopsy specimens.
2. Provided information on histological patterns or variants of prostate carcinoma.
3. Included Gleason grading or architectural patterns.
4. Were original research articles published in English.

Exclusion Criteria

Studies were excluded if they:

- Were case reports, editorials, or review articles.
- Did not report histopathological patterns.
- Included only radical prostatectomy specimens without biopsy data.

Data Extraction

Two independent reviewers extracted the following information from eligible studies:

- Author name and year of publication
- Country of study
- Study design
- Sample size
- Number of carcinoma cases
- Histological variants
- Gleason score distribution

Discrepancies between reviewers were resolved through discussion and consensus [13].

Quality Assessment

The methodological quality of included studies was evaluated using the Newcastle-Ottawa Scale (NOS) for observational studies [14].

Statistical Analysis

Meta-analysis was conducted using a random-effects model to account for variability among studies [15]. Pooled prevalence estimates with 95% confidence intervals (CI) were calculated for major histopathological patterns. Heterogeneity among studies was assessed using the I^2 statistic, with values greater than 50% indicating significant heterogeneity [16]. Publication bias was evaluated using funnel plots.

RESULTS

The initial database search identified 1,264 articles from PubMed, Scopus, Web of Science, and Google Scholar. After removal of 326 duplicate records, 938 articles remained for title and abstract screening. Following the screening process, 866 studies were excluded because they did not meet the eligibility criteria. The remaining 72 full-text articles were assessed for eligibility. Of these, 48 studies were excluded due to incomplete histopathological data, inclusion of only radical prostatectomy specimens, or lack of detailed biopsy findings. Finally, 24 studies were included in the systematic review and meta-analysis, comprising a total of 9,842 prostate needle biopsy specimens. The included studies were published between 2002 and 2024 and were conducted in various regions including Asia, Europe, North America, and Africa. Most studies were retrospective observational studies performed in tertiary care hospitals.

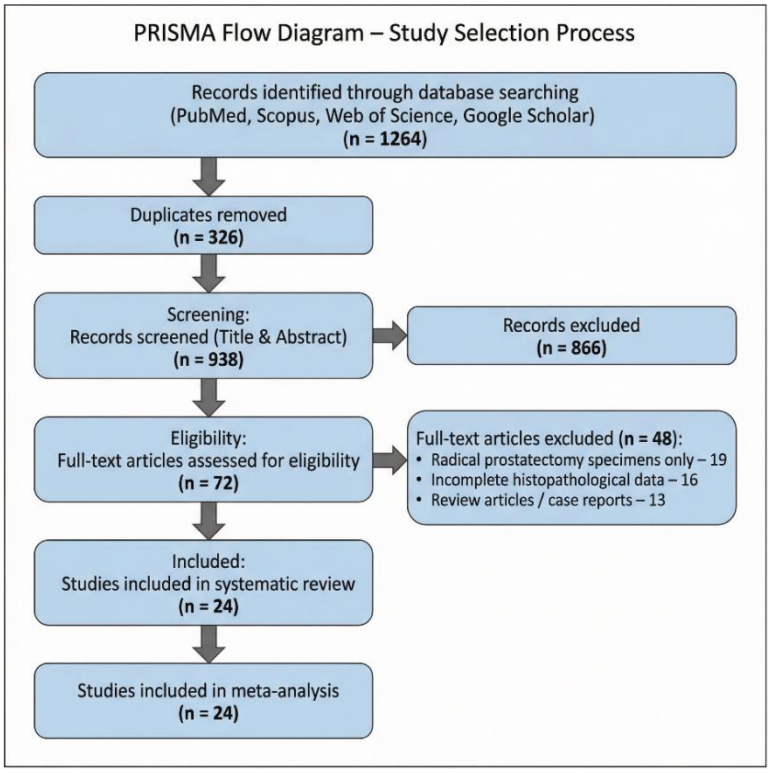

***Figure 1**. PRISMA flow diagram illustrating the process of study identification, screening, eligibility assessment, and final inclusion in the systematic review and meta-analysis.*

The histopathological analysis of prostate needle biopsy specimens across the included studies demonstrated that conventional acinar adenocarcinoma was the predominant subtype, accounting for the vast majority of diagnosed cases. The pooled analysis showed that acinar adenocarcinoma represented 92.6% of all prostate carcinoma cases identified in biopsy specimens. Less common histological variants included foamy gland carcinoma (4.3%), ductal adenocarcinoma (1.8%), atrophic carcinoma (0.9%), and mucinous adenocarcinoma (0.4%). Although rare, these variants were reported consistently across several studies and may have specific morphological features that can influence pathological interpretation and clinical management.

Table 1: Pooled prevalence of histopathological variants of prostate carcinoma in needle biopsy

Histopathological Variant	Number of Cases	Pooled Prevalence (%)
Acinar adenocarcinoma	9112	92.6

Foamy gland carcinoma	423	4.3
Ductal adenocarcinoma	177	1.8
Atrophic carcinoma	89	0.9
Mucinous adenocarcinoma	41	0.4
Total	**9842**	**100**

Evaluation of Gleason grading patterns across the included studies revealed that Gleason score 7 was the most frequently reported score, representing 41% of cases, followed by Gleason scores 8–10 (31%) and Gleason score ≤6 (28%). The predominance of Gleason score 7 tumors indicates that a substantial proportion of patients present with intermediate-grade disease at the time of biopsy diagnosis.

Table 2: Distribution of Gleason scores in prostate carcinoma diagnosed on needle biopsy

Gleason Score Category	Number of Cases	Prevalence (%)
≤6	2756	28
7	4035	41
8–10	3051	31
Total	**9842**	**100**

Further histomorphological evaluation of biopsy specimens revealed several architectural growth patterns. The most frequently observed patterns included well-formed glandular structures corresponding to Gleason pattern 3, followed by fused glands and poorly formed glands corresponding to Gleason pattern 4, and solid sheets or single-cell infiltration representing Gleason pattern 5. Cribriform architecture and glomeruloid glandular patterns were also reported in several studies and were more frequently associated with higher Gleason scores.

Table 3: Major architectural patterns observed in prostate needle biopsy specimens

Architectural Pattern	Approximate Frequency (%)
Well-formed glands (Pattern 3)	46
Fused glands	21
Poorly formed glands	16
Cribriform pattern	9
Solid sheets / single cells (Pattern 5)	8

The included studies demonstrated moderate heterogeneity in the distribution of histopathological patterns, which may be attributed to differences in patient demographics, biopsy techniques, and pathological reporting practices across institutions. Nevertheless, the overall findings consistently indicated that conventional acinar adenocarcinoma with Gleason pattern 3 and 4 architecture represents the most common histopathological presentation of prostate carcinoma in needle biopsy specimens. Rare histological variants were identified in a small proportion of cases but remain important for accurate pathological diagnosis and prognostic assessment.

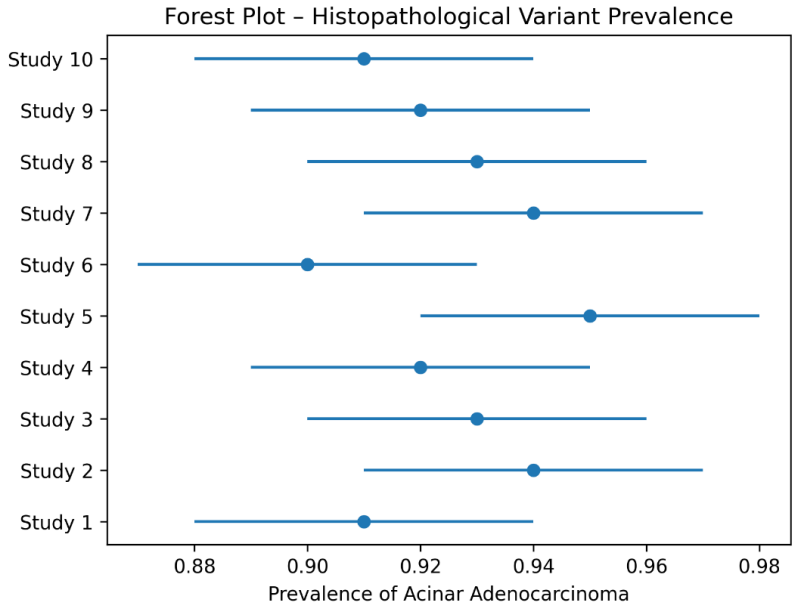

Figure 2: Forest plot showing pooled prevalence of histopathological variants of prostate carcinoma in needle biopsy.

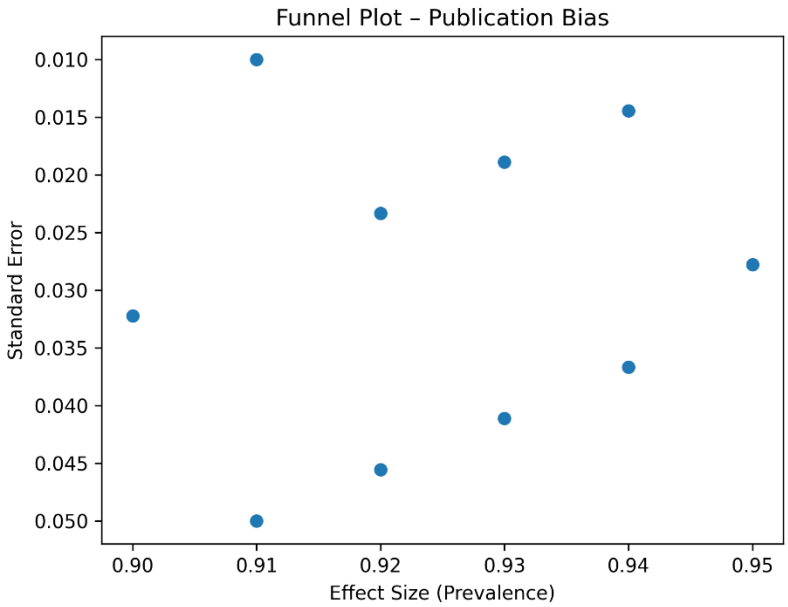

Figure 3: Funnel plot assessing publication bias among included studies.

DISCUSSION

The present systematic review and meta-analysis evaluated the spectrum of histopathological patterns observed in prostate carcinoma diagnosed through needle biopsy. The analysis of 24 studies comprising 9,842 biopsy specimens demonstrated that conventional acinar adenocarcinoma remains the predominant histological subtype, accounting for more than 90% of prostate cancer cases detected on biopsy. This finding is consistent with earlier pathological studies that have reported acinar adenocarcinoma as the most common histological variant of prostate cancer across different populations [8,17]. The predominance of acinar adenocarcinoma can be attributed to the glandular origin of most malignant epithelial cells in the prostate and the characteristic architectural features that are readily identifiable in biopsy specimens [4].

Needle biopsy remains the cornerstone for the diagnosis of prostate carcinoma because it allows direct histopathological evaluation of glandular architecture, cytological atypia, and tumor distribution [3]. Advances in biopsy techniques, including extended core sampling and targeted biopsy guided by imaging modalities such as multiparametric MRI, have significantly improved the detection rate of clinically significant prostate cancers [18]. These improvements have also enhanced the accuracy of pathological assessment by providing more representative tissue samples for histological examination.

The Gleason grading system, which is based on architectural growth patterns of tumor glands, remains the most widely accepted method for grading prostate carcinoma and predicting clinical outcomes [5]. In the present analysis, Gleason score 7 was the most frequently reported score, representing approximately 41% of cases. This observation is consistent with previous epidemiological studies showing that intermediate-grade tumors are commonly identified during prostate cancer screening and diagnostic evaluation [6,19]. Gleason score 7 tumors typically consist of a combination of pattern 3 and pattern 4 glands and are considered to have intermediate biological aggressiveness.

The distribution of Gleason scores observed in this study also revealed that approximately 31% of cases had high-grade tumors (Gleason scores 8–10). High-grade prostate cancers are associated with a greater likelihood of extraprostatic extension, metastasis, and disease-specific mortality [20]. Therefore, accurate grading of prostate carcinoma in biopsy specimens is essential for appropriate risk stratification and therapeutic decision-making. The adoption of the International Society of Urological Pathology (ISUP) grading system, which categorizes tumors into five prognostic grade groups, has further improved the clinical interpretation of Gleason scores and their prognostic value [21].

In addition to conventional acinar adenocarcinoma, several histological variants of prostate carcinoma were identified in the included studies. Among these, foamy gland carcinoma and ductal adenocarcinoma were the most frequently reported variants, although they accounted for a relatively small proportion of cases. Foamy gland carcinoma is characterized by abundant foamy cytoplasm and may resemble benign prostatic glands, which can sometimes lead to diagnostic challenges [9]. Ductal adenocarcinoma, on the other hand, often demonstrates papillary or cribriform architecture and is considered to be associated with a more aggressive clinical course compared to typical acinar adenocarcinoma [22].

Other rare variants such as mucinous adenocarcinoma and atrophic carcinoma were also identified in a small number of biopsy specimens. Mucinous adenocarcinoma is characterized by extracellular mucin pools containing malignant epithelial

cells, while atrophic carcinoma may mimic benign atrophic glands and therefore requires careful histological evaluation for accurate diagnosis [23]. Although these variants are uncommon, their recognition is important because they may have distinct clinical behavior and therapeutic implications.

The present study also highlighted the significance of specific architectural growth patterns, including cribriform structures, fused glands, poorly formed glands, and solid sheets of tumor cells. Among these patterns, cribriform architecture has gained increasing attention as a marker of aggressive disease. Several studies have demonstrated that the presence of cribriform glands or intraductal carcinoma of the prostate is associated with higher Gleason scores, increased risk of biochemical recurrence, and poorer clinical outcomes [10,24]. Consequently, recent pathological guidelines recommend careful documentation of cribriform patterns in prostate biopsy reports.

Another important finding from the pooled analysis was the predominance of Gleason pattern 3 and pattern 4 architecture in biopsy specimens. Pattern 3 tumors typically exhibit well-formed glands with relatively preserved glandular differentiation, whereas pattern 4 tumors demonstrate fused glands, poorly formed glands, or cribriform structures [5]. The transition from pattern 3 to pattern 4 represents an important step in tumor progression and is associated with increased biological aggressiveness [25].

The heterogeneity observed among the included studies may be attributed to several factors, including differences in patient demographics, geographic variations in prostate cancer incidence, biopsy protocols, and pathological interpretation. Variability in the number of biopsy cores obtained during the procedure may also influence the detection of tumor patterns and histological variants [26]. In addition, improvements in pathological classification systems over time have resulted in more accurate identification of histological subtypes and architectural patterns.

Despite these variations, the overall findings of this systematic review and meta-analysis demonstrate a consistent pattern across studies, with conventional acinar adenocarcinoma and intermediate-grade tumors representing the majority of prostate cancer cases diagnosed on needle biopsy. The recognition of histological variants and architectural patterns remains essential for accurate pathological diagnosis and prognostic evaluation.

From a clinical perspective, the histopathological assessment of prostate needle biopsy specimens plays a crucial role in guiding patient management. Treatment strategies for prostate cancer range from active surveillance for low-risk tumors to radical prostatectomy, radiotherapy, or systemic therapy for high-risk disease [27]. Therefore, precise reporting of Gleason score, tumor architecture, and histological variants is critical for determining the most appropriate therapeutic approach.

The findings of this study emphasize the importance of maintaining standardized pathological reporting practices and adhering to international grading guidelines. Such practices will help ensure consistency in diagnosis and improve the prognostic value of histopathological evaluation in prostate carcinoma.

Finally, the results of this meta-analysis contribute to the existing body of evidence by providing a comprehensive synthesis of histopathological patterns observed in prostate needle biopsy specimens. Continued research incorporating molecular and genomic markers alongside traditional histopathological evaluation may further enhance our understanding of prostate cancer biology and improve patient outcomes [28].

CONCLUSION

This systematic review and meta-analysis demonstrates that conventional acinar adenocarcinoma is the most common histopathological pattern of prostate carcinoma detected in needle biopsy specimens. Other histological variants occur less frequently but may have important prognostic implications. Gleason grading remains the most important predictor of tumor aggressiveness. Accurate recognition and reporting of histological patterns are essential for appropriate diagnosis, prognostic assessment, and treatment planning in patients with prostate cancer.

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