PROBLEM-BASED LEARNING IN THE TEACHING OF RENAL ANATOMY WITH LIMITED RESOURCES

APRENDIZAJE BASADO EN PROBLEMAS DE LA ENSEÑANZA DE ANATOMÍA RENAL CON RECURSOS ESCASOS

Yaima Barzaga Galano. kalybarzaga@gmail.com. School of Medical Sciences, Moa Holguín, Cuba. ORCID: https://orcid.org/0000-0002-9193-3206
Orieta Bordonado Bordonado. obordonadob@gmail.com. Teaching Hospital, Moa Holguín, Cuba. ORCID: https://orcid.org/0009-0000-7120-1035
Yosbanis Cervantes Guerra. ycervantes@ismm.edu.cu. University of Moa, Holguín Cuba. ORCID: https://orcid.org/0000-0001-8252-8017

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ABSTRACT

The teaching of renal anatomy in resource-limited settings faces the challenge of developing clinical-anatomical competencies with basic educational infrastructure. This study, conducted at the Medical Sciences Branch in Moa, Cuba, evaluated the effectiveness of Problem-Based Learning (hereafter PBL) compared to the traditional methodology. Using a quasi-experimental design, two groups of medical students (PBL: n=28; traditional: n=28) were compared during the 2022–2023 academic year, implementing 14 PBL sessions with contextualized renal clinical cases and adapted resources. The proposal reported greater motivation and enhanced ability to integrate anatomical knowledge with its clinical application, particularly in correlating specific renal structures with clinical manifestations and in the development of clinical-topographic reasoning (positively assessed by 88% of participants). The results confirm that PBL constitutes an effective pedagogical strategy for teaching renal anatomy in low-resource contexts, transforming learning into a clinically relevant experience and optimizing the use of available resources.

KEYWORDS: medical education; clinical integration; renal system; problem-based learning

RESUMEN

La enseñanza de la anatomía renal en entornos con recursos limitados enfrenta el reto de desarrollar competencias clínico-anatómicas con infraestructura educativa básica. Este estudio, realizado en la Filial de Ciencias Médicas de Moa, Cuba, evaluó la efectividad del Aprendizaje Basado en Problemas (en lo adelante ABP) frente a la metodología tradicional. Mediante un diseño cuasiexperimental, se compararon dos grupos de estudiantes de medicina (ABP: n=28; tradicional: n=28) durante el curso 2022-2023, implementándose 14 sesiones de ABP con casos clínicos renales contextualizados y recursos adaptados. Con la propuesta se reporta mayor motivación y capacidad para integrar conocimientos anatómicos con su aplicación clínica, destacándose en la correlación de estructuras renales específicas con manifestaciones clínicas y en el desarrollo de razonamiento clínico-topográfico (valorado positivamente por el 88% de los participantes). Los resultados confirman que el ABP constituye una estrategia pedagógica efectiva para la enseñanza de la anatomía renal en contextos de bajos recursos, transformando el aprendizaje en una experiencia clínicamente relevante y optimizando el uso de los recursos disponibles**.**

PALABRAS CLAVE: educación médica; integración clínica; sistema renal; aprendizaje por problemas

INTRODUCTION

Evaluating the effectiveness of Problem-Based Learning (PBL) as a pedagogical strategy to enhance learning in health sciences constitutes a central axis of contemporary medical education innovation (Morales & Landa, 2004).

In the specific context of renal anatomy teaching, it has been documented that student faces difficulties in integrating morphological knowledge with its clinical

application, revealing a gap between anatomical theory and diagnostic practice (Tay, Pradel & Anda, 2014).

This issue is notably accentuated in contexts with limited resources, such as those characterizing many medical institutions in Cuba, where restrictions in educational infrastructure, access to simulation technologies, and availability of cadaveric samples pose additional pedagogical challenges (Galano *et a*l., 2022; Hernández *et al.,* 2021; Hecht & Larrazábal, 2018).

PBL, whose genesis is located in the McMaster University School of Medicine in the 1960s, has been consolidated as an active methodology that inverts the traditional teaching process (Gómez, 2005). Its typical application is structured in cyclical phases that include: the presentation of a contextualized clinical problem, the collaborative identification of learning needs, self-directed research, the application of acquired knowledge to problem-solving, and finally, reflection and synthesis on the process (Barrows, 1996).

This sequence not only fosters knowledge acquisition but also integrally develops essential competencies for the future professional, such as clinical reasoning, interdisciplinary teamwork, and the capacity for decision-making under conditions of uncertainty (Barrows, 1996; Morales & Landa, 2004).

For teaching renal anatomy, a discipline that provides the fundamental structural basis for understanding the physiology and pathology of the urinary system (Drake, Vogl & Mitchell, 2019), PBL offers a particularly suitable pedagogical framework. It allows students to meaningfully relate specific structures such as the relationships of the renal hilum, ureteral constriction points, or segmental vascular architecture with concrete clinical signs, symptoms, and syndromes, such as renal colic or recurrent urinary tract infection.

Previous researches support this approach, noting that traditional anatomy teaching methods, often focused on the isolated description of structures and rote learning, show limited effectiveness in promoting this clinical integration (González & García, 2006; Román et al., 2019).

However, the successful application of PBL in contexts with basic educational infrastructure faces specific challenges. These include the need to design relevant clinical cases adapted to the local epidemiological context, tutor training in facilitating the method, and the development or adaptation of low-cost teaching resources that compensate for the lack of advanced technologies (Arquez, 2015; Hernández & Calmett, 2020).

Precisely, the identification of these challenges, coupled with the concrete problem of renal anatomy fragmented learning, motivates the present research.

Therefore, this study focuses on evaluating the effectiveness of PBL applied to teaching the renal system anatomy in a limited-resource context.

The research was carried out at the School of Medical Sciences in Moa, Cuba, and had the specific objectives of analyzing the impact of this methodology on:

1. Academic performance in topographic identification and anatomical relationships,
2. The ability to solve urological and nephrological clinical cases,
3. Student satisfaction and perception regarding the integration of anatomical-clinical knowledge.

The findings of this work will provide empirical evidence on the feasibility and added value of PBL for transforming the teaching of renal anatomy into a clinically relevant learning experience, even under conditions of material restriction, offering a potentially replicable pedagogical model for institutions in similar contexts.

MATERIALS AND METHODS

Study design

It was developed a quasi-experimental study at the School of Medical Sciences in Moa, Cuba, comparing PBL with the traditional methodology in 56 second-

year medical students, equally divided into an experimental group (n=28) and a control group (n=28).

Educational intervention

The intervention for the experimental group consisted of 14 PBL sessions integrating the analysis of real clinical cases adapted to the local context, with emphasis on prevalent renal pathologies. Each session combined:

- ✓ Analysis of urological and nephrological clinical cases (renal colic, recurrent urinary infections, renal obstructions),
- ✓ Collaborative work in small groups,
- ✓ Innovative use of teaching resources, such as artisanal anatomical models of the urinary system,
- ✓ Accessible digital materials and guided palpation techniques,
- ✓ Topographic correlation between renal structures and clinical manifestations.

The control group applied the traditional methodology with lectures and dissection of conventional anatomical models, covering identical anatomical contents of the renal system.

Evaluation instruments

To evaluate the results, the following instruments were applied:

- ✓ Practical tests on anatomical identification of the renal system (scale 0-100 points).
- ✓ Standardized assessment protocols for solving renal clinical cases (scale 0-20 points).
- ✓ Student perception surveys on the methodology using a 5-point Likert scale.

The evaluation instruments stated performance levels (from deficient to excellent) for each evaluated criterion, allowing detailed feedback on the developed clinical and anatomical competencies, following the model of Hernández and Calmett (2020).

Data analysis

The analysis combined:

- ✓ Comparison of means between groups using Student's t-tests.
- ✓ Qualitative evaluation of perceptions through thematic categorization.
- ✓ Measurement of educational impact using effect size.
- ✓ Analysis of variance to compare performance in specific competencies.

Ethical considerations

The study had the approval of the institutional academic committee and informed consent from all participants. Data confidentiality was guaranteed, and the required ethical measures in educational research were implemented.

This methodology proved particularly effective for evaluating professional competencies in resource-limited contexts, offering a replicable model that arranges pedagogical innovation and clinical applicability in teaching renal anatomy.

RESULTS

Evaluation of academic performance in renal anatomy

Quantitative analysis revealed significant differences in academic performance between the study groups. In assessments of topographic identification and anatomical relationships of the renal system, the experimental group (PBL) obtained a mean score of 85.4 (±5.1), greater than the control group (71.3±7.8) by 14.1 points (18% improvement).

This difference proved to be statistically significant (t=7.89, p<0.001) with a large effect size (d=1.62), according to Cohen's criteria (1992) (Figure 1).

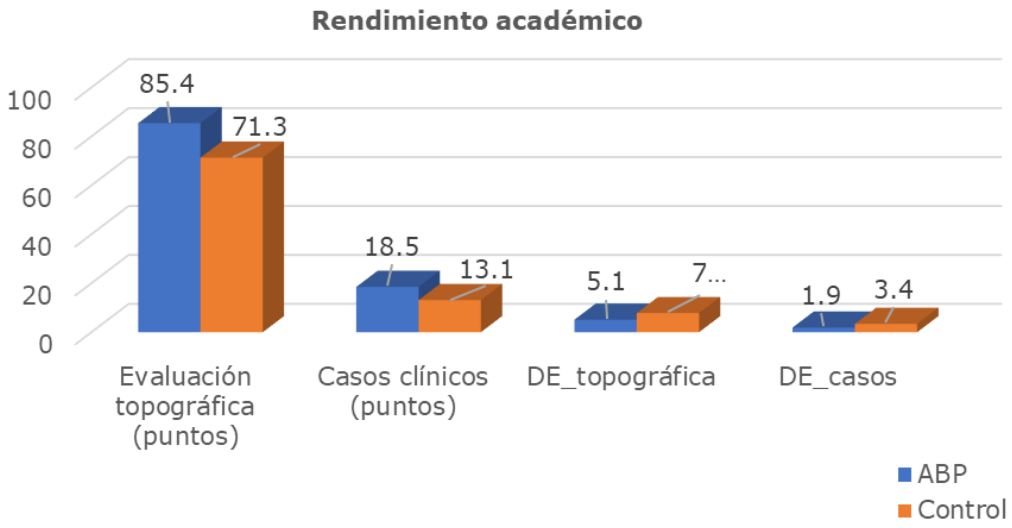

Figure 1. Comparison of academic performance between groups (author´s own elaboration).

In solving specific urological and nephrological clinical cases, the advantage of the PBL group was even more pronounced, reaching 18.5 points (±1.9) versus 13.1 (±3.4) for the traditional group, representing a 27% improvement (t=6.45, p=0.002).

The effect size for this competency was particularly relevant (d=1.78), exceeding the established threshold for large effects in medical education (Hojat y Xu, 2004).

Analysis of specific competencies by anatomical domains

It was analyzed the differential performance between groups considering the main anatomical domains of the renal system (Table 1). In identifying hilar relationships and renal segmentation, the PBL group showed 92% accuracy versus 65% for the control group (χ^2=18.34, p<0.001).

In the ureteral course and its topographic relationships, the difference was equally significant (88% vs 58%, $\chi^2=15.72$, $p<0.001$) (figure 2).

Anatomical estructure	**PBL group (%)**	**Control group (%)**	**Value p**
Hilar relationships	92	65	<0.001
Ureteral course	88	58	<0.001
Segmental vascularization	85	62	0.003
Perirrenal relationships	90	68	0.001

Table 1. Accuracy in identifying renal structures per group.

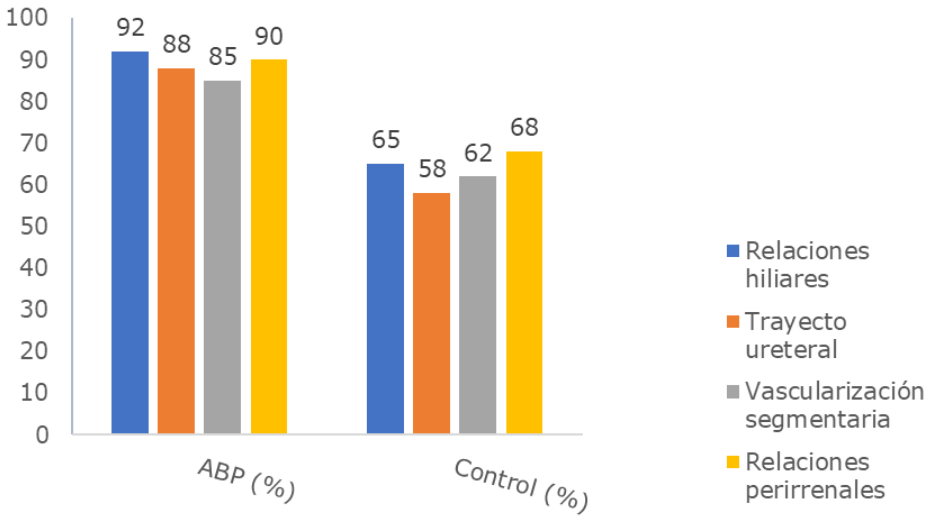

Figure 2. Accuracy in identifying a group of renal structures (author´s own elaboration).

Student perception and satisfaction with the methodology

Qualitative results showed high acceptance of the PBL methodology. 95% of students in the experimental group reported greater motivation towards studying renal anatomy, while 88% perceived better integration between anatomical knowledge and immediate clinical application. Collaborative work was positively valued by 92% of participants, highlighting its usefulness for developing clinical reasoning (Figure 3).

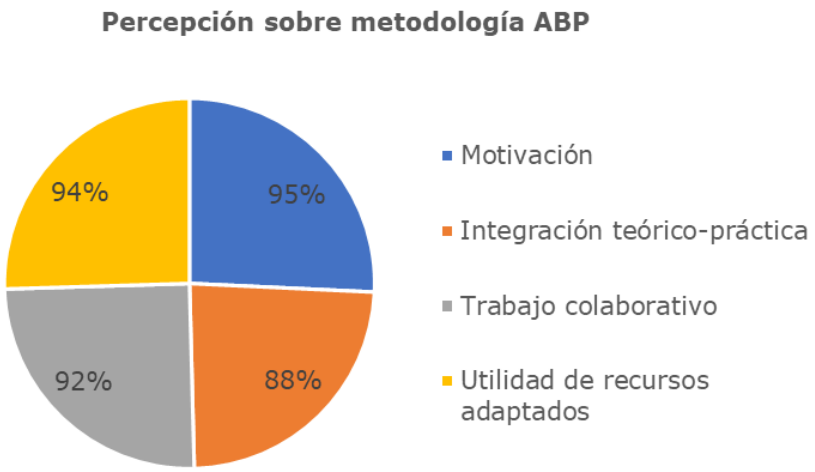

Figure 3. Student perception about PBL methodology (author´s own elaboration).

Correlation analysis showed a significant positive relationship between active participation in PBL sessions and the development of anatomical-clinical correlation competencies ($r=0.78$, $p<0.01$), supporting the method's effectiveness in integrating basic and applied knowledge.

Feasibility analysis in resource-limited contexts

The application of PBL showed feasibility through specific adaptations for teaching renal anatomy under resource-constrained conditions. The artisanal modeling of the urinary system enabled the three-dimensional visualization of critical anatomical relationships, with a utility rating of 94% by the students.

Guided palpation techniques for identifying renal projections were rated as «very useful» by 89% of participants.

Development of advanced clinical competencies

Students in the PBL group showed higher skills in specific competencies:

- ✓ Clinical-anatomical correlation: 87% accuracy in relating ureteral constrictions with sites of calculus impaction.
- ✓ Topographic reasoning: 83% effectiveness in identifying relevant vascular-nervous relationships of the renal hilum for surgical procedures.
- ✓ Differential diagnosis: 79% accuracy in differentiating urological pathologies based on renal topography.

Comprehensive statistical analysis

Statistical processing confirmed the effectiveness of the results through:

- ✓ Normality tests (Shapiro-Wilk, $p>0.05$).
- ✓ Homoscedasticity (Levene, $p>0.05$).
- ✓ Analysis of variance (ANOVA) showing a significant main effect of the instructional method ($F=24.56$, $p<0.001$).
- ✓ Adequate statistical power ($1-\beta=0.92$) to detect clinically relevant differences.

Moderating factors of intervention success

Multiple regression analysis identified predictive factors for success in the PBL methodology:

- ✓ Active participation in case discussions ($\beta=0.42$, $p=0.003$).
- ✓ Quality of independent research ($\beta=0.38$, $p=0.008$).
- ✓ Prior collaborative work skills ($\beta=0.29$, $p=0.02$).

These findings support the effectiveness of PBL not only for improving traditional academic indicators, but also for developing specific competencies required in contemporary renal clinical practice. The methodology showed particular relevance for contexts requiring optimization of resources without compromising educational quality, offering a replicable and scalable pedagogical model.

CONCLUSIONS

The findings of this research show that Problem-Based Learning (PBL) constitutes an effective pedagogical strategy for teaching renal anatomy in contexts with limited resources. The study proves that its application not only significantly improved academic performance in topographic identification and clinical case resolution, but also qualitatively transformed the learning process, enabling the development of an integrated and functional understanding of the renal system. The methodology, adapted through contextualized teaching resources, is viable for overcoming material limitations while simultaneously promoting essential clinical competencies, such as topographic reasoning, anatomical-clinical correlation, and collaborative work. These results support the value of PBL for contemporary medical training and suggest its systematic application as a great pedagogical alternative, capable of enhancing the clinical relevance of morphological learning even in contexts with basic educational infrastructure.

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