

Article

ERCP Knowledge, Practical Skills, and Training Needs of Endoscopic Nurses: A Cross-Sectional Study Based on Miller's Pyramid Theory

Lingyun Liu¹, Jiajie Hu¹, Ling Tong¹, Qinyan Wang^{1,*}¹Department of Nursing, Sir Run Run Shaw Hospital, Zhejiang University School of Medicine, 310016 Hangzhou, Zhejiang, China*Correspondence: wangqy@zju.edu.cn (Qinyan Wang)

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Abstract

Aims/Background: Endoscopic retrograde cholangiopancreatography (ERCP) is a high-risk invasive procedure that requires close cooperation between physicians and specialized nurses. Standardized systematic training for endoscopic nurses remains insufficient in many clinical settings in China. We aimed to investigate current levels of specialized knowledge and practical skills among endoscopic nurses in Zhejiang Province, China regarding ERCP, based on Miller's pyramid theory of abilities, and analyze their training willingness and needs, thereby providing a theoretical basis for establishing a systematic and standardized ERCP training system for acquiring specialized knowledge and operational skills. **Methods:** We designed a questionnaire based on Miller's Pyramid of Clinical Competence and conducted a cross-sectional survey from August 2025 to September 2025 using convenience sampling among 230 endoscopy center nurses from 18 hospitals in Zhejiang. The questionnaire comprised three sections: general information, self-assessment of ERCP basic knowledge and practical skills, and training willingness and needs. The total survey score was 40 points, with 8–24 points indicating a low level, 25–34 points indicating a moderate level, and >34 points indicating a high level. **Results:** In total, 230 valid questionnaires were returned. The overall score for endoscopic nurses' ERCP knowledge level was 23.55 ± 5.81 points and that for practical skills was 23.77 ± 6.98 points; thus, nurses' knowledge and practical skill scores were both at a low level. Male nurses, nurses in tertiary A hospitals, nurses aged >40 years, those with intermediate-level professional titles or above, and nurses with >10 years' working experience achieved higher scores in theoretical knowledge and practical abilities. Analysis of endoscopic nurses' training needs revealed that 99.57% of nurses were willing to participate in training. Regarding the most common responses, these were "once per quarter" for training frequency, "Monday to Friday noon" for training time, "31–45 minutes" for training duration, "learning new techniques" for training content, and "hands-on practice in the operating room" for training methods; and the most common responses regarding training resources were "operation video library". **Conclusion:** The present findings indicated that endoscopic nurses' specialized knowledge and practical skills regarding ERCP require further improvement, and a clear demand for training exists. It is recommended that hospital administrators and nursing educators identify practical problems according to nurses' core demands and develop individualized hierarchical and staged training programs, with equal emphasis on theoretical knowledge and clinical practice. Teaching modalities including simulation training devices and hands-on workshops should be provided to foster professional specialization among ERCP nursing teams and improve patient safety outcomes.

Keywords: endoscopy; endoscopic retrograde cholangiopancreatography; education; cross-sectional study; nursing training; Miller's pyramid

1. Introduction

Endoscopic retrograde cholangiopancreatography (ERCP) is an advanced endoscopic technique combined with X-ray contrast imaging, which serves as an important method for the diagnosis and treatment of various biliary and pancreatic diseases [1]. ERCP is widely used in clinical practice owing to its advantages of minimal invasiveness, rapid recovery, and lower rates of complication, as compared with surgical procedures [2]. However, owing to its high operational difficulty, long learning curve, and important potential risks, ERCP is considered one of the most challenging procedures in endoscopic technology, requiring a high skill level among ERCP nursing staff [3]. Studies have shown that if nurses have not received specialized training in ERCP, the associated surgery time,

infection rates, and patients' medical costs may be increased [4]. Therefore, skilled nursing assistance is crucial for improving surgical success rates. Studies have shown that, as core members of the surgical team, endoscopic nurses should possess extensive knowledge of anatomy, pathophysiology, and pharmacology, along with proficient skills in equipment operation, instrument preprocessing, and emergency management. Furthermore, researchers such as Teles de Campos et al. [5] have pointed out that experienced nursing teams can significantly reduce surgery time, increase success rates, and lower the incidence of intraoperative and postoperative complications.

Miller's Pyramid of Clinical Competence [6], proposed by American physician and psychologist George E. Miller in 1990, is divided into four levels: knowledge,



competence, performance, and practice in the professional environment. This model is a widely used and effective tool for training and evaluating clinical health care professionals. Foreign studies have shown that clinical skill training grounded in Miller's competency pyramid can effectively improve clinical procedural skills among nursing students and novice nurses [7]. This model provides a theoretical framework and supervisory criteria for the training of emergency medical staff and optimizes the objectives of stratified training [8]. The theoretical model can also be applied to teaching and assessment in medical schools [9]. In domestic research, nurses in Hong Kong, China have achieved satisfactory outcomes in disaster response by adopting Miller's pyramid theory [10]. Tong et al. [11] reported that training based on Miller's pyramid theory helped interventional specialty nurses better master specialized knowledge and operational skills, as well as strengthen their critical thinking abilities. Currently, few studies in China have investigated the specialized knowledge level and training needs in ERCP among endoscopic nurses. Therefore, in this study, we aimed to investigate the current status of specialized knowledge and practical skills as well as training needs among ERCP nurses in Zhejiang, using a survey based on Miller's Pyramid of Clinical Competence, to provide preliminary evidence for formulating standardized regional training schemes.

2. Methods

2.1 Research Participants

Using convenience sampling, from August 2025 to September 2025, endoscopy nurses from the endoscopic centers of 18 hospitals performing ERCP in Zhejiang Province, China were enrolled as research participants.

The inclusion criteria were as follows: (1) possessing a nursing practice certificate; (2) received ERCP nursing training for ≥ 6 months or obtained the ERCP specialized nursing certificate issued by the Zhejiang Nursing Association; (3) ≥ 1 year of ERCP working experience completed; (4) voluntarily agreeing to participate in this study.

We excluded (1) interns, visiting scholars, and rotating nurses; (2) nurses who had taken >1 months' leave in the previous 6 months, including long-term sick leave, maternity leave, off-site study, and other types of leave.

2.2 Research Methods

2.2.1 Survey Instrument

Based on a comprehensive literature review and after consultation with endoscopy experts (physicians and nurses holding associate senior titles or above with over 10 years of endoscopic clinical practice), we incorporated Miller's pyramid model as the theoretical framework. This model segments clinical competence into four levels: knows, knows how, shows how, and does. Subsequently, we developed a questionnaire assessing the current ERCP training

status and needs of endoscopic nurses based on this model. The specific structure is described below.

(1) General demographic data were used to evaluate the impact of different background factors (education level, years of work experience) on competency levels. These data included sex, age, hospital level, years of work experience, education level, professional title, and years of ERCP experience, among others.

(2) We used a Self-Assessment Scale for ERCP Specialized Knowledge and Practical Skills, which is closely aligned with Miller's pyramid dimensions of knows, knows how, shows how and does. This scale uses a 5-point Likert scale for quantitative assessment. The Cronbach's alpha coefficient of this scale was 0.926, and the test-retest reliability was 0.835. The item-level content validity index ranged from 0.846 to 0.926, and the scale-level content validity index was 0.983. This scale comprised two sections. Each item of both the specialized knowledge scale and practical ability scale was scored on a 5-point scale, ranging from "Very familiar" (5 points) to "Very unskilled" (1 point). Based on consultations with two senior endoscopic nursing specialists who had at least 10 years of ERCP clinical experience and associate senior professional titles, cut-off values of 60% (24 points) and 85% (34 points) of the total questionnaire score were established for competency stratification. A third expert was consulted to resolve any evaluation discrepancies. To facilitate statistical analysis, the final classification criteria were defined as follows: scores <25 indicated a low level, 25–34 represented a moderate level, and >34 corresponded to a high level.

(i) Specialized knowledge: Theoretical positioning: this dimension evaluates nurses' static knowledge in the ERCP field, focusing on what is known. Included items (total of eight items) cover topics including the anatomical structure of the pancreatobiliary system, ERCP-related physiology and pathology, indications and contraindications, actions and adverse reactions of common contrast agents and medications, infection control and aseptic techniques, equipment principles and functions, radiation safety and protection, and identification and management of common complications. The total score ranges from 8 to 40 points, with higher scores indicating a stronger knowledge base.

(ii) Practical ability (Clinical reasoning & decision-making, Simulated clinical practice, Independent clinical practice): this dimension assesses nurses' ability to translate knowledge into action in clinical situations (i.e., knows how, shows how and does). This includes proficiency in operational procedures and the ability to address problems in simulated or real environments. Items (eight items in total) include patient assessment and preparation, preoperative preparation and inspection of endoscopes and accessories, standardized operation of various instruments, key points of cooperation under fluoroscopy, intraoperative patient monitoring, early recognition of complications and

Table 1. Correspondence between scale dimensions and levels of Miller's pyramid of clinical competence.

Scale dimension	Corresponding Miller's pyramid level	Core definition of each level	ERCP nursing scenarios
Theoretical knowledge	Knows	Basic ERCP knowledge, including equipment connection, pharmacology, equipment principles, and so on.	Able to accurately describe the indications and adverse effects of routine medications used during ERCP procedures (e.g., contrast agents, antispasmodic drugs).
Clinical reasoning & decision-making	Knows how	Analyze clinical information and develop intervention plans.	Able to identify the cause of intraoperative hemorrhage immediately after sphincterotomy and formulate hemostatic strategies.
Simulated clinical practice	Shows how	Demonstrate standardized operational procedures in a simulated environment.	Able to perform standardized guidewire placement and stone extraction coordination under simulated training conditions.
Independent clinical practice	Does	Independently implement clinical skills in real clinical environments without continuous supervision.	Able to independently undertake full-process nursing work for patients receiving ERCP in daily clinical work.

Note: ERCP, endoscopic retrograde cholangiopancreatography.

assistance with resuscitation, equipment maintenance and troubleshooting, and radiation protection measures. The total score ranges from 8 to 40 points, with higher scores indicating stronger practical translation ability.

(3) Based on the assessment results from the preceding two parts, the Training Status and Training Demand Scale portion inversely deduces training gaps. By analyzing the discrepancy between “knows” and “shows how”, this scale identifies weak links in the current training system, thereby precisely targeting future directions with respect to training needs. This section contains single-choice and multiple-choice questions, rather than a comprehensive rating scale. Participants selected items and ranked them in order of priority. No quantitative scoring for individual items or total scale scores was calculated. Descriptive frequency and constituent ratio analyses were adopted for these data. Multiple selections were allowed for each questionnaire item. All questionnaires were self-rated anonymously by the participating endoscopic nurses. According to Miller's competency pyramid framework, every dimension of the questionnaire corresponds to its respective theoretical tier, as shown in Table 1.

2.2.2 Survey Methodology

An electronic questionnaire was generated through the “Wenjuanxing” platform and distributed to the internal endoscopy center workgroups of each hospital, with the assistance of the Endoscopic Nursing Professional Committee and relevant hospital head nurses. Detailed informed consent information was provided at the beginning of the questionnaire. Standardized instructions were given to explain precautions when completing the questionnaire. Participants had the right to stop filling out the questionnaire and

withdraw from the survey at any time. Only fully completed questionnaires were included in the final analysis. After questionnaire collection, logical consistency and completeness were examined. A questionnaire was defined as invalid and excluded from analysis if it met any of the following criteria: missing items, excessively short completion duration, repeated submissions, obvious logical inconsistencies, or identical choices marked for all scale items. All participants completed the questionnaire anonymously, and no personally identifiable information was collected in this survey. Original research data were saved in a password-encrypted electronic file, and access was restricted exclusively to members of the research group.

2.2.3 Statistical Methods

In the analysis, we performed the Shapiro–Wilk test for normality and Levene's test for homogeneity of variances. Data analysis was conducted using IBM SPSS Statistics 26.0 for Windows (IBM Corporation, Armonk, NY, USA). Descriptive statistics were used to summarize quantitative data, reported as mean $\pm$ standard deviation. Statistical tests such as the independent-samples *t*-test and one-way analysis of variance were conducted. Frequency and percentage were used to describe categorical data. $p < 0.05$ was considered statistically significant.

3. Results

3.1 General Information

A total of 236 questionnaires were distributed, with 230 valid questionnaires returned, resulting in an effective response rate of 97.46%. Among participants, 80.87% were women; respondents' mean age was 35.80 ± 6.92 years; most had a bachelor's degree (95.22%); and the most

Table 2. Univariate analysis of ERCP specialized knowledge level among endoscopic nurses.

	Number	Score	<i>t/F</i> value	<i>p</i> value
Sex				
Female	186	22.92 ± 5.89	-3.453 [#]	0.001
Male	44	26.20 ± 4.62		
Hospital level				
Grade A tertiary	185	24.36 ± 5.61	6.790*	<0.001
Grade B tertiary	28	20.54 ± 5.73		
Grade A secondary	14	19.86 ± 5.56		
Grade B secondary	3	18.67 ± 3.06		
Age				
≤30	53	21.21 ± 5.11	8.955*	<0.001
30–40	129	23.62 ± 6.15		
>40	48	25.94 ± 4.53		
Years of work experience				
≤5 year	38	20.68 ± 4.01	6.128*	0.003
5–10 year	39	23.44 ± 6.17		
>10 year	153	24.29 ± 5.90		
Years of ERCP experience				
1–3 year	34	20.18 ± 3.66	7.085*	0.001
3–6 year	26	24.00 ± 6.08		
>6 year	170	24.15 ± 5.91		
Professional title				
Junior professional	67	22.04 ± 5.19	6.878*	0.001
Intermediate title	147	23.78 ± 5.95		
Senior professional	16	27.75 ± 4.70		
Qualification				
Junior college or below	6	21.33 ± 1.97	0.747*	0.475
undergraduate	219	23.56 ± 5.86		
Master's degree and above	5	25.60 ± 6.35		

Note: * represents the *F*-value, [#] represents *t*-value.

common professional title was an intermediate-level title (63.91%). Scores among endoscopic nurses for the specialized knowledge section of the assessment scale were 23.55 ± 5.81 , indicating a low level, and these were 23.77 ± 6.98 for the practical skills section, also suggesting a low level.

3.2 Endoscopic Nurses' ERCP Specialized Knowledge and Practical Skill Level Single-Factor Analysis

Our study results indicated that specialized knowledge was influenced by sex, hospital level, age, years of work experience, years of ERCP experience and professional title ($p < 0.05$), as shown in Table 2. Practical skills were influenced by sex, hospital level, age, years of work experience, and professional title ($p < 0.05$), as presented in Table 3.

3.3 Endoscopic Nurses' Training Willingness

Regarding training needs, 99.57% of endoscopic nurses expressed willingness to participate in training. The most preferred training frequency was “once per quarter” (45.65%), followed by “once a month” (26.52%). Regarding training scheduling, the largest proportion preferred “Monday to Friday noon” (42.60%), followed by “Mon-

day to Friday evenings” (26.96%). Regarding training duration, “31–45 minutes” accounted for the largest proportion (44.35%), followed by “15–30 minutes” (32.17%), as shown in Table 4.

3.4 Endoscopic Nurses' Training Needs

Among respondents, training content was predominantly focused on “learning new techniques” (37.39%), followed by “enhancing skills in various equipment operations” (26.09%). The findings indicated that endoscopy nurses had a strong willingness to receive training in new techniques and instrument operation skills, which suggested that they possess a proactive attitude towards professional development and a strong desire to enhance their clinical competencies. The preferred training method was “practical hands-on experience in the operating room” (83.48%), followed by “practical workshops” (79.13%). These data revealed that endoscopy nurses regarded on-site shadowing training highly, possibly because this model involves face-to-face instruction and immediate feedback. In terms of trainers, respondents' preference was for “senior doctors or nurses from the hospital” (81.30%), followed by

Table 3. Univariate analysis of ERCP practical ability level of endoscopic nurses.

	Number	Score	<i>t/F</i> value	<i>p</i> value
Sex				
Female	186	22.73 ± 6.87	-4.939 [#]	<0.001
Male	44	28.23 ± 5.55		
Hospital level				
Grade A tertiary	185	24.64 ± 6.88	5.848*	0.001
Grade B tertiary	28	20.89 ± 5.47		
Grade A secondary	14	20.00 ± 7.33		
Grade B secondary	3	15.00 ± 7.55		
Age				
≤30	53	23.01 ± 7.13	8.962*	<0.001
30–40	129	22.73 ± 6.85		
>40	48	27.44 ± 5.96		
Years of work experience				
≤5 year	38	23.58 ± 6.44	3.387*	0.036
5–10 year	39	21.26 ± 7.88		
>10 year	153	24.47 ± 6.75		
Years of ERCP experience				
1–3 year	34	24.24 ± 6.00	2.357*	0.097
3–6 year	26	21.00 ± 7.54		
>6 year	170	24.11 ± 7.01		
Professional title				
Junior professional	67	22.72 ± 7.02	4.080*	0.018
Intermediate title	147	23.78 ± 7.01		
Senior professional	16	28.19 ± 4.65		
Qualification				
Junior college or below	6	19.50 ± 4.68	2.678*	0.071
undergraduate	219	23.77 ± 7.00		
Master's degree and above	5	29.20 ± 5.07		

Note: * represents the *F*-value, [#] represents *t*-value.

Table 4. Endoscopic nurses' ERCP knowledge and skills training willingness.

Option	Frequency (n)	Proportion (%)
Training frequency		
Once per quarter	105	45.65%
Once a month	61	26.52%
Twice a year	45	19.57%
Once a week	15	6.52%
Once a year	3	1.30%
Not willing to participate in training	1	0.43%
Training time		
Monday to Friday noon	98	42.60%
Monday to Friday evening	62	26.96%
Weekends	39	16.96%
Before work, Monday to Friday	18	7.83%
Department meeting time	13	5.65%
Training Duration		
31–45 min	102	44.35%
15–30 min	74	32.17%
46–60 min	37	16.09%
Half a day	17	7.39%

Table 5. Endoscopic nurses' ERCP knowledge and skills training needs.

Option	Frequency (n)	Proportion (%)
Training content		
Learning new techniques	86	37.39%
Cooperation skills for operating various instruments	60	26.09%
Knowledge of ERCP complication management	57	24.78%
Radiation protection knowledge and personal protective measures	15	6.52%
Cooperation skills for complex procedures	12	5.22%
Training methods		
One-on-one hands-on practice in the operating room with a mentor	192	83.48%
Practical skills workshop	182	79.13%
Case study discussions	171	74.35%
Online learning	152	66.09%
Trainers		
Invited in-house medical staff with associate senior title or above	187	81.30%
In-house teaching staff	162	70.43%
Renowned experts nationwide	158	68.70%
External invited medical staff with associate senior title or above	156	67.83%
Training resources		
Operation video library	198	86.09%
Hands-on practice opportunities	185	80.43%
Simulation training equipment	177	76.96%
Instrument Atlas Manual	162	70.43%

“our teaching staff” (70.43%). The most desired training resource was the “operation video library” (86.09%), followed by “hands-on practice opportunities” (80.43%). A combination of an operative video library, bedside shadowing, and simulation training equipment can not only provide standardized procedural videos but can also improve nurses' confidence in clinical practice after fundamental training on simulators (Table 5).

4. Discussion

This survey revealed that both specialized knowledge and practical skills were significantly influenced by sex, hospital level, age, years of work experience, and professional title. Professional knowledge is also significantly affected by years of ERCP experience. Nurses with higher seniority, superior titles, and more extensive collaboration experience achieved higher scores, reflecting the pronounced experience-dependent nature of ERCP nursing competence [10]. Owing to their abundant cases, comprehensive equipment and accessories, and ample training resources, tertiary A hospitals exhibit a higher overall skill level among their nurses. Nurses with longer work experience have participated in more ERCP procedures, accumulated richer clinical experience, and have had the opportunity to continuously learn and master relevant knowledge in practice [12,13]. Male nurses achieved higher scores in specialized theoretical knowledge and practical competency. ERCP nursing work requires staff to wear heavy lead aprons during procedures, carry equipment, and position patients. A previous study has confirmed that male nurses possess bet-

ter physical fitness and stronger stress resistance, making them physically more adaptable to such high-intensity work [14]. This finding may also be attributed to greater professional self-confidence among men. A survey of clinical trainers reported that 95% of respondents believed that male sex was associated with greater confidence levels [15]. These differences suggest the importance of considering the impact of professional experience and institutional support on the development of nursing capabilities.

According to our survey results, the vast majority of nurses demonstrated a strong willingness to undergo training. This finding suggests there is an urgent need among endoscopy nurses to enhance their ERCP professional capabilities. These training needs are diverse and specific. In terms of training format and scheduling, 45.65% of our respondents preferred quarterly training sessions. Additionally, 44.35% favored training sessions lasting between 31 and 45 min, and 42.60% desired training provided on weekdays at noon to avoid disrupting their weekend rest and to allow for better integration of the training content with clinical work. Regarding training content, 37.39% of nurses expressed a wish to learn about new ERCP technologies and advancements, followed by learning skills to assist in difficult surgeries and to operate various types of equipment. These findings reflect an urgent need among endoscopy nurses to update their knowledge and operational skills so as to keep pace with medical advancements in ERCP technology. The training methods most favored by our respondents were practical, hands-on approaches such as practice in the operating room and work-

shops in practical operations. These approaches are highly effective and highlight nurses' preference for learning by doing [16]. Additionally, the "operating video library" stood out as the most popular training resource, indicating that visual and repeatable learning materials play a crucial role in skills training [17,18]. Internationally, professional societies including the European Society of Gastrointestinal Endoscopy (ESGE) and the European Society of Gastroenterology and Endoscopy Nurses and Associates (ESGENA) have released consensus statements outlining core competency requirements and standardized training pathways for endoscopy nurses participating in ERCP procedures [19]. These international frameworks emphasize systematic training covering theoretical knowledge, procedural simulation, intra-procedural collaboration and emergency response capabilities, which aligns with the competency dimensions adopted in the present study based on Miller's Pyramid. A recent rapid review further highlighted that well-resourced overseas training systems adopt mandatory long-term structured courses combined with objective practical assessments to guarantee the proficiency of nurses undertaking advanced endoscopic interventions such as ERCP [20]. Nevertheless, endoscopic nurses in Zhejiang Province mainly acquire ERCP-related skills through informal on-the-job learning and ad hoc short-term training opportunities. This discrepancy helps explain the substantial training demands identified among participants in our survey. Benchmarking our findings against international recommendations highlights the necessity to develop localized, hierarchical ERCP training schemes for Chinese endoscopic nurses to bridge gaps in specialized competency development.

ERCP nurses with lower hospital levels, less experience, lower professional titles generally exhibited lower levels of specialized knowledge and coordination abilities, making them a target group for ERCP system training. Notably, practical ability scores presented a U-shaped trend across clinical experience and ERCP experience subgroups. Nurses with shorter clinical experience (≤ 5 years) and ERCP experience (1–3 years) achieved relatively higher scores, likely because they had recently received standardized systematic training and rigorously adhered to operational protocols. In contrast, nurses with 5–10 years of clinical experience or 3–6 years of ERCP experience may develop fixed operating habits and inadvertently deviate from standard protocols, resulting in lower scores. However, as clinical experience continues to accumulate, senior nurses effectively integrate standardized guidelines with practical expertise, contributing to a subsequent increase in practical ability scores [18]. Recommendations for this group include establishing a comprehensive training system as well as delivering systematic learning ranging from basic anatomy and radiation protection to mechanisms of procedural complications, to remedy inadequate knowledge at the "knows" level. A video learning library can help

in translating abstract theories into standardized procedural protocols, allowing nurses to repeatedly watch and analyze operational breakdowns, thereby building an intuitive cognitive foundation for the "knows how" stage. The critical bottleneck for endoscopy nurses is the disconnection between possessing knowledge and performing clinical tasks. Restricted by limited experience in assisting, these nurses lack solid muscle memory, and their operative movements tend to deteriorate when facing complicated procedures. Hands-on practical workshops create a low-risk training setting in which nurses can repeatedly practice segmented skills, including papillary cannulation and instrument delivery using simulators or *ex-vivo* specimens until standardized muscle memory is firmly established. This serves to consolidate professional competency at Miller's "shows how" level. Sufficient on-site shadowing opportunities should be guaranteed to ensure adequate clinical practice within a fixed period. For junior nurses at the "does" level, the primary obstacle is cognitive overload. Their cognitive resources are fully occupied by fundamental knowledge and operational steps, leaving little mental capacity to anticipate the endoscopist's maneuvers and monitor patients' vital signs. To address this problem, nurses should first assist in simple ERCP procedures. After accumulating substantial foundational experience, these nurses can gradually take part in more complex surgeries. This progressive training approach enables nurses with limited working and assisting experience to achieve competency advancement from basic proficiency to expert clinical performance.

This study has several limitations. First, the survey only included endoscopy nurses from certain hospitals in Zhejiang Province as participants, resulting in a relatively small sample size. Future studies could expand the sample size and recruit endoscopic nurses with limited ERCP experience or without official ERCP certification from hospitals in different regions and of different grades, so as to improve the representativeness and generalizability of the study findings. Second, convenience sampling was adopted in this study, which is susceptible to confounding factors. Therefore, a clear causal relationship between variables cannot be derived. Subsequent stratified random sampling should be used to further verify the relationship between variables. Additionally, all data were collected using self-reported questionnaires, which may lead to reporting bias. Subjective self-evaluation may cause overestimation or underestimation of personal clinical competence, reducing the objectivity of research results. Notably, the questionnaire relies on subjective self-assessment and cannot objectively measure the "Does" level of Miller's Pyramid of Clinical Competence. We interpret the study findings prudently to avoid overstating the practical implementation of the theoretical framework. To mitigate self-report bias, future research can integrate objective simulation skill assessments and conduct cross-verification with intraoperative nursing quality control records to complement sub-

jective questionnaire data and achieve multi-dimensional verification of nurses' actual clinical capabilities. Moreover, this study did not involve the development of targeted hierarchical training strategies tailored to nurses with different hospital levels, working years, and professional titles. Differentiated training programs should be formulated specifically for junior nurses, senior nurses, and nurses working in primary-level hospitals. In the future, research teams should conduct long-term follow-up studies on training effectiveness, incorporating objective evaluation indicators such as simulation-based assessment, procedural performance scoring, and complication response evaluation. Constructing standardized objective evaluation metrics can effectively compensate for the deficiency of single self-reported measurement and improve the accuracy and credibility of competency evaluation. After the implementation of training, the theoretical knowledge, operational skills, and clinical competency of nurses should be regularly evaluated to evaluate the training results and existing limitations, so that the training program can be timely and optimized accordingly, so as to provide a basis for establishing a scientific and effective ERCP professional training system for endoscopic nurses.

5. Conclusion

Based on Miller's pyramid theory, this study established a comprehensive framework evaluating professional knowledge, application abilities, technical performance, and practical performance. Our survey findings indicated that specialized knowledge and skills in ERCP among endoscopy nurses in Zhejiang Province are at a low level, with nurses having high training needs and strong willingness to participate in training, especially in learning new technologies and coordinating the operation of various types of equipment. The findings reveal the current status of endoscopy nurses' knowledge and abilities in the field of ERCP and highlight their urgent educational needs. Future efforts should be directed toward developing demand-driven and practice-centered standardized training courses, as well as establishing a sustainable training and assessment mechanism to comprehensively enhance the quality of ERCP nursing care. Ultimately, this will ensure medical safety and improve patient outcomes.

Key Points

- In this cross-sectional study, grounded in Miller's Pyramid of Clinical Competence, we evaluated ERCP-related specialized knowledge and practical skills among endoscopic nurses across Zhejiang Province, China, clarifying the current status of hierarchical professional competency in regional endoscopic nursing.
- Endoscopic nurses in Zhejiang Province demonstrated overall low levels of ERCP specialized knowledge and practical skills, highlighting a general deficiency in

ERCP professional competency among the surveyed nursing workforce.

- ERCP competency varied significantly by demographic characteristics, with male nurses, tertiary hospital nurses, nurses with intermediate professional titles and above, and those with more than 10 years of work experience achieving higher knowledge and skill scores.

- Nearly all participating nurses showed positive willingness to receive ERCP training, with clear preferences regarding the specific training frequency, time arrangements, duration, technical content, bedside practical learning, and video-based training resources.

- Targeted hierarchical and staged training programs that integrate theoretical teaching, simulation equipment, and hands-on workshops are essential to address existing competency gaps, promote ERCP nursing specialization, and enhance patient procedural safety.

Availability of Data and Materials

The datasets used or analyzed during the current study are available from the corresponding author upon reasonable request.

Author Contributions

LYL, JJH, LT: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Resources; Supervision; Validation; Visualization; Writing—original draft; and Writing—review & editing. QYW: Conceptualization; Methodology; Project administration; Supervision; Writing—review & editing. All authors gave final approval of the version to be published. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

This study was in line with the ethical principles laid down in the Declaration of Helsinki. Consent was obtained directly from nurses. Patients and/or the public were not involved in the design, conduct, reporting, or dissemination plans of this research.

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Conflicts of Interest

The authors declare no conflicts of interest.

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