

Techniques for Images Processing, Factors and Results of Colposcopy to Diagnose Cervical Cancer

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Abstract: *The colposcopy is a test that is performed if you have related symptoms with cancer or if the result of Pap smears test gives an abnormal cells; however, it has a continue problem because there are few doctors who know about colposcopy and it leads to misinterpretation. Therefore, in the last years various proposals have emerged to solve this problem. The present study aims to identify the current state of the latest research related to the detection of cervical cancer during the colposcopy test using the image evaluation. A framework is proposed based on 3 research questions: (1) What techniques are used for image processing with colposcopy to diagnose cervical cancer? (2) What are the factors that help diagnose cervical cancer during colposcopy? And (3) What results corroborate or provide the diagnosis produced by the colposcopy test in the detection of cervical cancer? One of the results proposes that the use of Convolution Neural Network (CNN) improves the sensitivity of the diagnosis of cervical cancer, since it achieved greater precision in colposcopy image processing. Furthermore, the diagnosis can be corroborated with the "results" of the "Biopsy" and "Expert Judgment".*

Keywords: *Colposcopy, Colposcopy techniques, Colposcopy image, Convolutional Neuronal Network.*

I. INTRODUCTION

Cervical cancer is a disease in which malignant (cancer) cells form in the tissues of the cervix" [1]. One of the ways to detect this cancer is with a test called colposcopy. It is a test that is performed in case of having certain symptoms that suggest cancer or if the Pap test gives an abnormal cell result [2], this test was born in 1925 with the article by Dr. Hans Peter Hinselman called "Improvement of possibilities of inspection of the vulva, vagina and cervix" where the magnification that was achieved with the power of colposcopic vision is emphasized, this advantage being reflected with the clarification of diagnoses, especially in discovering new initial cases of cervical cancer. Over the years, he obtained the so-called "boom period", although with the latent problem of having very few who knew about colposcopy and subsequent misinterpretation, due to the lack of a constant between the visual changes of the cervical epithelium and the severity of pre-neoplasm. invasive or invasive, and poor judgment of poorly prepared colposcopists, a problem that we retain to this day but to a lesser extent [3]. In colposcopy the key instrument for a

proper diagnosis is the colposcope, which varied little from its creation to the current ones. On the most current colposcope it is defined as a binocular microscope with which the Epithelium and the sub-epithelial vascular network can be examined. an amplification that can vary from 7.5X to 30X [4]. In 2018 the project of the International Cancer Research Center (by its initials, IARC), an organ that is part of the World Health Organization, called the World Cancer Observatory, released a compilation of data on cancer incidences and its mortality in Globocan 2018. The IARC showed the estimation of new cancer cases and their mortality in the world in women in 2018, with cervical cancer for both cases being the fourth with the highest number with 569 847 and 311 365 respectively [5]. In addition, the global data at Globocan 2018 the IARC showed the estimates of new cancer cases and mortality in Peru in women in 2018, with cervical cancer being the second with 4103 and the third with 1836 respectively [6]. Therefore, different proposals have emerged that contributed to the diagnosis of cervical cancer with the colposcopy test. In this article, a systematic review of the literature has been carried out according to a proposed taxonomy, in order to identify future research. The present work is organized in the following way. In section II, we present the research methodology for the systematic review of the literature on works related to the detection of cervical cancer during colposcopy or using a similar process of image capture of the affected area, in this case the cervix. Then in the section III presents the studies used for the present work and their classification according to our taxonomy. Section IV presents the analysis of the results of the systematic literature review. Finally, in section V are the conclusions regarding what has been developed.

II. RESEARCH METHODOLOGY

This systematic literature review has considered the methodology presented in the work by Wong et al. [7] based on the guidelines of Kitchenham et al., which consist of the following steps: (i) Planning the review: in this phase, the research questions are prepared and the review protocol is defined. (ii) Conducting the review: in this phase, primary studies are chosen in accordance with the selection and exclusion protocol. And, (iii) Reporting the review: in this phase, the statistical analyses run on the selected studies are presented.

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A. Planning

In this phase, the following research questions were considered: RQ1: What techniques are used for image processing with colposcopy to diagnose cervical cancer? RQ2: What are the factors that contribute to a diagnosis of cervical cancer during a colposcopy? RQ3: What results corroborate or provide the diagnosis produced by the colposcopy test in the detection of cervical cancer?

The following data bases were used to conduct searches: Scient Direct, MedlinePlus, LILACS, Wiley and BMC. The period of time covered by the search was January 2015 to July 2020. The following search sequence was used: TITLE-ABS-KEY (“colposcopy techniques”) or TITLE-ABS-KEY (“colposcopy image”) or TITLE-ABS-KEY (“Convolutional Neural Network”), which has been used in the title, abstract, and key words. After, the selection and exclusion criteria shown in Table I were applied.

Table I: Selection and exclusion criteria

Selection Criteria	Exclusion Criteria
Studies related to the state of the art and motivation.	Study sources other than research journal articles.
Relationship with obtaining the activity.	Studies outside the 6-year range (2015-2020).
Techniques used for colposcopy image processing.	Information that is not in the English or Spanish language.
Factors that help for a colposcopy test.	Information that is not related to the medical area and image processing.
Examinations that corroborate the results of the colposcopy test.	

^a The criteria allow to exclude and identify the literatures necessary for the research

B. Development the Review

This phase explains the development of the review process considering the databases, the search statement and the selection and exclusion criteria found in Table I. The flow chart of the search process is shown in Fig. 1.

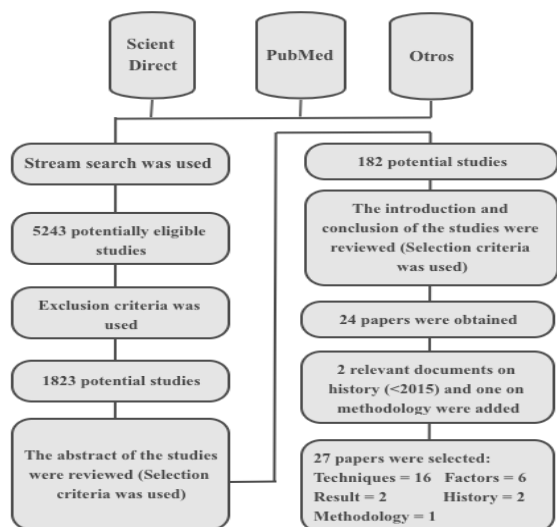


Fig. 1 Systematic literature review process.

C. Result of the Review

In this phase, the results of the search are shown, where

5243 were found and 24 were selected after using the exclusion and selection criteria, and two important studies were added regarding the history and 1 of the methodology used in this work. During the process, the studies were analyzed to answer the different questions. Table II shows the number of studies for each source.

Table II: Potentially eligible studies and selected studies

Sources	Potentially Eligible Studies	Selected Studies
ScientDirect	2281	11
PubMed	2512	7
Otros	450	9
Total	5243	27

^b Data from searches in sources, then selection and exclusion criteria are applied.

Fig. 2 shows the studies related to the years requirements (2015 - 2020), in addition to the 3 used in the rest of the content, 2 for the introduction (<2015) and one for methodology. These 27 studies correspond to different aspects of colposcopy, its techniques, factors and results, in addition to those used in the rest of the content.

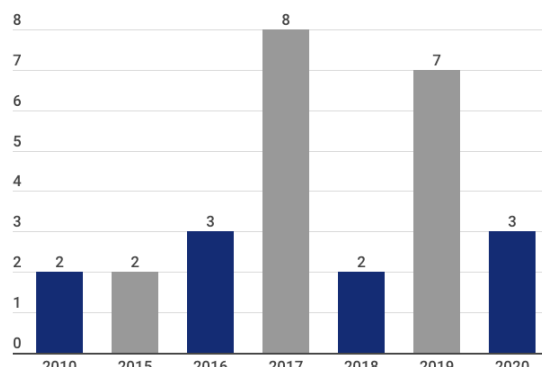


Fig. 2 Studies used in this research divided according to their year of publication.

III. TAXONOMY

The following taxonomy is proposed (see Fig. 3) for the analysis of the results obtained in the literature review on works related to the detection of cervical cancer with the colposcopy test: "Techniques" (RQ1), "Factors" (RQ2) and "Results" (RQ3). Each classification is related to the research questions raised in point IIA. The "Techniques" classification is related to the work on the use of tools, processes and / or techniques for diagnosis of cervical cancer with colposcopy or image processing, the "Factors" classification, with works on those characteristics that help and influence the diagnosis of cervical cancer and the "Results" classification, with works on those tests that corroborate or provide the results of the colposcopy test.

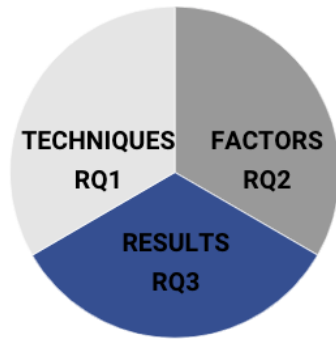


Fig. 3 General framework proposed for the literature review.

In summary, Table III shows the studies found in the literature according to the proposed taxonomy.

Table III: Study classification summary

Classification	References	Total
Techniques	[8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23]	16
Factors	[24, 25, 26, 27, 28, 29]	6
Results	[10, 11, 16, 17, 18, 19, 30, 31]	8
Total		30

^c The studies were divided according to a classification that helps to better understand the literature.

A. Techniques

Table IV shows studies in relation to the techniques used during the colposcopy and which support a cervical cancer diagnosis, such as the RCI, Colposcopy DIS, HRME, CDP, Apps and CNN, each one with its respective sources.

Table IV: Techniques used during colposcopy

Techniques	References
RCI	[8,9]
Colposcopic DSI	[10,11,12,13,14]
HRME	[15]
CDP	[16]
Smartphones	[17,18,19]
CNN	[20,21,22,23]

^d Techniques used to process colposcopy images

Boonlikit [8] sought to evaluate the performance of the Reid Colposcopic Index (RCI) by analyzing medical records; they concluded that the performance of the abbreviated RCI is good amongst women with abnormal cytology. In another study [9], they compared the Swiss Score with the RCI Score, demonstrating that both worked well in a hospital study with a selected population, furthermore a Swiss Score of 8 or more has a specificity of 100%.

In the analysis of Colposcopy and Dynamic Spectral Imaging (DSI) and Conventional Colposcopy (CC) by Louwers et al. [10], they obtained greater sensitivity with DSI than with CC, and a similar sensitivity in low and high grade cytology with DSI. Another study of DSI concluded that the sensitivity between low and high grade cytology were similar [11]. On the other hand, Coronado and Fasero [12] analyzed CC against DSI and CC and found that this combination had a

greater sensitivity than either procedure on its own. In another study, Kaufmann et al. [13] concluded that DSI technology increases colposcopy sensitivity to 88% when it is used as a complement to CC. Finally, a colposcopy study on Dynamic Spectral Imaging System (DySIS) found that DySIS is more sensitive than CC [14].

Parra et al. [15] evaluated the feasibility and clinical performance of the High-resolution microendoscopy (HRME) concluding that the site specificity of the colposcopy, followed by HRME images, was significantly greater than the CC, as it generated a reduction in biopsies.

De Castro et al. [16] proposed the Cervical Digital Photography (CDP) as an alternative to the CC; amongst their conclusions they learned that CDP could improve the detection of cervical cancer, but it depended on where it was implemented, the challenges of each location, and if it was colposcopists who evaluated the images.

Tanaka et al. [17] proposed a pilot study named “Smartscope” that used smartphones to capture cervical images, the results of which were corroborated by CC and were 85% accurate. Afterward [18] they tried it again with flash mode activated and captured images of the cervix while still and in motion; as a result, “Smartscope” identified a patient that was not identified with CC, and 59 were identified by both. Gallay et al. [19] utilized this application, called “Exam”, to measure the detection of cervical cancer that resulted in a quality image in the context of detection with CC and could offer an alternative to images taken by a colposcope.

Kaur et al. [20], they proposed a method called Colponet for classification of colposcopy images, this method was based on the DenseNet model due to its efficiency, they achieved an accuracy of 81.353% and also a higher performance rate compared to other techniques; while Bui et al. [21], using the MobileNetV2 model, they obtained an accuracy of 91.66% for a binary classification and 83.33% a classification of four classes. In the same way, the Cervigram-based Recurrent Convulsive Neural Network (C-RCNN) [22] showed different grades of CIN labeled by gynecologists and obtained a test precision of 96.13% with a specificity and sensitivity of 98.22% and 95.09%. Finally, Zang et al. [23] applied deep learning technology and proposed a method of diagnosing cervical precancerous lesions based on CNN with the DenseNet model, where they obtained an accuracy of 73.08%.

B. Factors

Table V shows studies in relation to various factors and/or characteristics that support a cervical cancer diagnosis during the colposcopy, such as postcoital bleeding, lesions, experience with the test, main signs and pregnancy, each with its respective sources.

Table V: Factors during colposcopy

Factors	References
Postcoital bleeding	[24]
Injuries	[25,26]
Test Experience	[27]
Main Signs	[28]
Pregnancy	[29]

^c Within the literature we find key factors for the diagnosis of cervical cancer.

Godfrey et al. [24] mentioned that postcoital bleeding is a worrying symptom for women and an important sign of cervical cancer, for this reason they proposed a study of women referred for a colposcopy with postcoital bleeding, concluding that a history of negative or inadequate cytology, or no previous history of cytology, had no significant correlation with the clinical result of a high degree of dysplasia or cancer. Marujo et al. [25], in their study, describe cytological lesions, classifying the colposcopic findings as “normal” or “abnormal”. Abnormal lesions are classified as grade 1 (minor change) if one observes fine mosaics, fine punctation, and a thin acetowhite epithelium with an irregular geographic border, or grade 2 (major change) if one observes a dense acetowhite epithelium and coarse mosaics or punctation. Another study by Zhang et al. [26] lists one of its objects as evaluating the factors associated with the diagnosis of High Grade Squamous Intraepithelial Lesion (HSIL). As a result, they obtained a diagnostic accuracy of approximately 80%, associated with the symptoms, the result of the cytology, the colposcopy diagnosis and the number of biopsies; furthermore, they indicated an overdiagnosis or underdiagnosis of HSIL through a colposcopic biopsy.

Pop et al. [27] mentions that patient satisfaction during the colposcopy is important for compliance and continuity of care. The result of their survey demonstrated that young women and those with little education are those who should receive special attention. Beyer et al. [28] analyzed the nomenclature the International Federation of Cervical Pathology (IFCPC) with CC (leukoplakia, coarse mosaics and punctuation, dense acetowhitening, sharp borders, signs of crest and atypical blood vessels). They conclude that only the coarse punctuation and mosaics, following by dense acetowhitening, will achieve predictive values for CIN2+ lesions. Ciavattini et al. [29] defines the optimal period during pregnancy to complete a colposcopy, with it being more reliable in the first half of pregnancy or in the first two trimesters, since after the 20th week of gestation the accuracy and reliability may be reduced and may be due to the polypoid or exophytic appearance of the cervix.

C. Results

Table VI shows the studies related to the tests used to corroborate the "Results" returned by the colposcopy test or image processing in the detection of cervical cancer, for example, biopsy, cytology and expert judgment, each one with their respective sources.

Table VI: Results that corroborate the diagnosis

Results	Reference
Biopsy	[30,31,16]
Cytology	[31,10,11]
Expert Judgment	[17,18,19]

Baasland et al. [30] compared the results of the colposcopy and their biopsies to identify the correct answers with the colposcopy, obtaining a sensitivity in this alone to detect CIN2 + of 61%. On the other hand, Abolafia et al. [31] carried out descriptive analyzes with categorical variables (cytology, colposcopy and biopsy), finding that the degree of agreement was better between colposcopy and biopsy ($k = 0.57$, 95% CI 0.47-0.68). Finally, in the research mentioned in the CDP technique [16], they used biopsies if the case required it, obtaining an improvement in the detection of cervical cancer.

As previously mentioned by Abolafia et al. [31] found that the agreement between cytology and colposcopy verified by the Kappa index was insignificant ($k = 0.16$; 95% CI 0.09-0.22). For the analysis of their studies that analyze the DSI technique, previously explained, they used cytology as a result of comparison, concluding that the sensitivity of DSI colposcopy between low and high grade cytology was very similar [10, 11]. During the “Smartcopy” study they used expert judgment for their research, resulting in more than 80% correct answers in both studies [17, 18]. Finally, in the application called “Exam” they used gynecologists to evaluate the images, concluding that the quality of the images produced can potentially be integrated in the context of CC detection [19].

IV. ANALYSIS OF THE RESULTS

A. Techniques (RQ1)

According to the results obtained in the analysis, 16 studies correspond to different "techniques" used during the colposcopy exam such as: RCI, DSI, HRME, CDP, Smartphones and CNN; These represent 53.33% of the total number of studies reviewed, where it is observed that most of the studies apply the “technique” DSI [10-14]; for example, Louwers et al. [10] using DSI obtained greater sensitivity than CC and a similar sensitivity in low and high grade cytology. On the other hand, the least used “techniques” are: HRME [15] and CDP [16]. However, the technique with the highest average accuracy is CNN (see Table IV).

B. Factors (RQ2)

Of all the studies analyzed for this work, 6 belong to the "factors" and / or characteristics that help diagnose cervical cancer during colposcopy, for example: postcoital bleeding, injuries, test experience, main signs and pregnancy. These studies represent 20% of the total. Where it is observed that most of the works are focused on “Lesions” [25, 26]; for example,



Marujo et al. [25] in their study, they describe cytological lesions, classifying colposcopic findings as "normal" or "abnormal." In addition, the other "factors" have the same number of studies analyzed (see Table V).

C. Results (RQ3)

Regarding the works related to the "Results", were obtained in the analysis 8 works (26.66 %) corresponding to the different examinations to confirm the diagnosis of the colposcopy, these are: biopsy, cytology and expert judgment.

Where it is observed that there are an equal number of studies analyzed for the different "results" such as "Biopsy" [30, 31, 16], "Cytology" [31, 10, 11] and "Expert judgment" [17-19] (see Table VI).

D. Cross Analysis "Techniques" vs "Results"

To have a deeper analysis of the different contributions that have been seen previously, a cross analysis has been carried out between: "Techniques" applied in colposcopy and the tests used to corroborate the "results". Table VII shows the analysis of these related contributions, where "Expert Judgment" is used in all the "techniques" applied in colposcopy [8-23]; and the "Cytology" is only used in the techniques of "DSI" [10, 11] and "Smartphones" [17].

Table VII: "Techniques" vs "Results"

Results Techniques	Biopsy	Cytology	Expert Judgment
RCI	[8,9]		[8,9]
DSI	[11,12,13,14]	[10,11]	[10,11,12,13,14]
HRME			[15]
CDP			[16]
Smartphone		[17]	[17,18,19]
CNN	[23]		[20,21,22,23]

^f The diagnoses of the techniques used are corroborated with the results of three tests.

V. CONCLUSION

In the present study, 5243 articles were found related to different factors, results techniques, and techniques for cervical cancer detection based on colposcopy, to which, a systematic literature review has been made, obtaining 24 relevant articles after applying the selection and exclusion criteria which were defined in Section II. The taxonomy that was proposed in this study corresponds to the three research questions which were elaborated in the review planning: RQ1, RQ2 y RQ3 (see Section II.A). Among the "Techniques" for cervical cancer diagnosis are: RCI, DSI, HRME, CDP, Smartphones and CNN; being "DSI" the most used in the revised articles. Among the "Factors" which influence colposcopy, the one that has been mentioned in most studies is "Lesions", while, for other factors, the same number of studies was found, such as: "Postcoital bleeding", "Test Experience", "Main Signs" and "Pregnancy". Finally, the same number of studies for "Results", which corroborate or provide the diagnosis of colposcopy, were found, and these consisted of "Biopsy", "Cytology" and "Expert Judgment".

A cross analysis has been made between the components of the proposed taxonomy ("techniques" and "results"), where it

has been found that "Expert Judgment" was used in all techniques for cervical cancer diagnosis (see Table VII). Lastly, the use of CNN for colposcopy image processing is proposed because it achieved greater precision and improved the sensitivity of the diagnosis of cervical cancer. In addition, the diagnosis is corroborated with the results of the "Biopsy" and "Expert Judgment".

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