Correlation of Necrotizing Enterocolitis (NEC) on Radiology Examination of Plain Abdomen Photo and Ultrasonography (USG)

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Abstract

Introduction: Necrotizing enterocolitis (NEC) is an inflammatory condition caused by infectious agents with a background of immaturity of local defense mechanisms and hypoxic-ischemic damage to the intestinal mucosa. Plain abdominal radiography can be used to examine this condition. The results of diagnostic imaging of the neonatal gastrointestinal tract have relatively limited accuracy, and limit improvements in diagnostic efforts and determine the severity. The results of the examination can also be used with ultrasound. This study aims to analyze the correlation of NEC examination using plain radiography and ultrasound. Methods: This type of research uses a retrospective cohort study. The subjects of the study were 39 patients who underwent plain radiography and ultrasound examinations related to NEC conditions. The data source for this study is secondary data obtained through an intermediary media, namely PACS. The secondary data source for this study is data that has been recorded at the Radiology Installation of Dr. Hasan Sadikin General Hospital, Bandung in the period January 2023-June 2024. The Spearman correlation test was used to test the hypothesis of a correlation between NEC examinations using plain radiography and ultrasound. Results: The results of the Spearman correlation test showed no significant correlation between NEC examination using plain radiographs and USG with a correlation coefficient value of 0.138. The findings that can be taken from this study are that there is an increase in grade in patients who undergo USG examination. This finding proves the importance of conducting USG examination to confirm NEC conditions more accurately. Conclusion: There is no significant correlation between NEC examination using plain radiographs and USG. Examination using USG can confirm NEC more accurately, as evidenced by an increase in grade in 43.58% of study subjects.

Keywords: Necrotizing enterocolitis, Premature, Plain abdominal X-ray, USG.

1. Introduction

Today, major improvements in neonatal intensive care have reduced the mortality rate in premature infants. With improved survival of premature infants. One condition in premature infants that has experienced this increase is Necrotizing Enterocolitis (NEC), which is becoming a more common condition1. NEC is a complex, multifactorial condition. Identified risk factors include premature birth, low birth weight, and formula feeding. Genetic factors may also play a role. The worldwide incidence varies from 0.3 to 2.4 infants per 1000 live births. Nearly 70% of these cases occur in premature infants born before 36 weeks of gestation. NEC in premature infants is the result of a multifactorial process that requires the concomitant presence of an immature intestinal tract and immune system leading to increased susceptibility, factors that disrupt the normal intestinal bacterial microbiome with the growth of potentially pathogenic bacteria, and an exaggerated inflammatory host response with release of cytokines and chemokines.3,5 NEC symptoms may be insidious and subtle at first, including feeding intolerance, but can rapidly progress to fulminant NEC with characteristic signs such as pneumatosis intestinalis and/or portal venous gas. In neonates with NEC who require surgery to remove the perforated bowel, the mortality rate is estimated to be between 20 and 30%, the highest among neonates requiring surgery. Neonates who do not require surgery are estimated to be hospitalized 20 days longer in the neonatal intensive care unit (NICU) than unaffected neonates, and neonates who require surgery are hospitalized an average of 60 days longer.[6]

The diagnosis of NEC is complicated because it lacks clinical diagnostic indicators with good specificity and high sensitivity. A combination of the following clinical signs is generally required: sudden onset of feeding intolerance, abdominal distension, bloody stools, and signs of sepsis (i.e., changes in heart rate, respiratory rate, temperature, and blood pressure) in premature infants. Furthermore, C-reactive protein and procalcitonin values in routine blood tests; acid and coagulation replacement in blood gas and electrolyte analyses; and blood, urine, stool, and cerebrospinal fluid culture results are considered in the pathogenesis. Because the clinical and laboratory features are nonspecific, the diagnosis of NEC is difficult and usually relies on the identification of pathognomonic signs on imaging.[9]

The most important method required to establish the diagnosis is a series of plain abdominal radiographs including anterior-posterior views and left lateral decubitus views. Plain radiographs can be used to reflect the stages of the process in the intestine. Patient examination is performed during the first day of suspicion with an interval of 6-8 hours, then images are performed according to indications. Clinical suspicion is very important for early recognition and effective treatment to drastically reduce morbidity and mortality of the disease.3,10

Anterior-posterior (AP) plain abdominal radiograph in the supine position showing normal versus abnormal bowel gas patterns; (A) Normal bowel gas pattern without evidence of NEC; (B) Progressively dilated bowel gas pattern, not specific for NEC as seen in many clinical conditions such as swallowed air in normal infants to inflamed bowel due to NEC and/or with postoperative ileus, (C) Continued dilatation of the bowel loops with some evidence of bowel wall edema.11

The results of the examination using diagnostic plain radiography can be correlated with ultrasonography (USG) results, which allow for further information regarding the detection of bowel loop dilation, delamination and thickening of the bowel wall, free fluid and gas in the abdominal cavity. Abdominal US allows the identification of many additional signs of NEC, which are not visible on radiographs, through real-time imaging of the bowel and peritoneum. The bowel wall can be directly marked, showing abnormal thickness (increased or decreased) and abnormal echogenicity. Distended bowel with fluid can be seen. In addition to bowel findings, small amounts of free intraperitoneal fluid can be identified, and the fluid can be described as simple or complex. Focal fluid collections or abscesses can be localized.[2,11]

Abdominal US is a non-invasive imaging modality with real-time results. Several studies have shown that USG is superior in the diagnosis, management, and prediction of outcome for NEC. USG can demonstrate echocardiographic signs of bowel wall, peristalsis, bowel wall blood perfusion, pneumatosis intestinalis, ascites, and free gas with sensitivity and specificity of up to 70 and 80%, respectively. The sensitivity of AUS for bowel necrosis (76.9 vs. 38.5%) and bowel perforation (61.5 vs. 15.4%) was higher than plain radiography. USG can be a useful adjunct in detecting changes consistent with NEC even when plain radiography is less clear and convincing. USG has a unique advantage in detecting perforation. The sensitivity and specificity for pneumoperitoneum are higher. USG has 100% sensitivity and 100% specificity for the diagnosis of perforation based on factors such as pneumoperitoneum, complex ascites, and intestinal wall blood supply.[12,13,14] Based on the background that has been described, the central theme of the study is as follows: NEC is an inflammatory condition caused by infectious agents with a background of immaturity of local defense mechanisms and hypoxic-ischemic damage to the intestinal mucosa. NEC generally occurs in premature infants born before 36 weeks of gestation. Risk factors for NEC include formula milk, antibiotic exposure, blood transfusion, etc. The method that can be used to examine this condition is a series of plain abdominal radiographs. The results of diagnostic imaging of the neonatal gastrointestinal tract have relatively limited accuracy, and limit improvements in diagnostic efforts and determine the level of severity. The results of the examination can also be used with, which USG can help evaluate NEC. On USG, pneumatosis intestinalis, portal vein gas, and free intraperitoneal air are more sensitive to these findings, and can be identified earlier. The researcher is interested in analyzing the correlation of NEC examination results using plain radiographs and abdominal USG considering that the correlation of both can be used to identify the condition more accurately. In connection with the description above and the absence of research on the correlation of NEC in plain radiological examinations and USG at Dr. Hasan Sadikin General Hospital, Bandung, the researcher is interested in conducting the study.

2. Research Method

This study design uses a retrospective cohort study, also known as a historical cohort study, conducted at the present time and looking back in time to examine medical events or outcomes. Subjects selected based on outcome data (i.e. disease status, event status), measured in the past, are reconstructed for analysis.[31]

Place and Time of the Study

This study was conducted in the NICU of Dr. Hasan Sadikin General Hospital (RSHS) Bandung which has a neonatal unit. Researchers included premature infants born at RSHS who were diagnosed with NEC and treated in the NICU between January 2023 and June 2024.

Research Population and Subjects

The target population in this study was all infants with necrotizing enterocolitis who had undergone abdominal x-ray and ultrasound examinations at Dr. Hasan Sadikin General Hospital, Bandung during the period January 2023 to June 2024.

Research Sampling

Sample size can be defined as the portion of the population needed to ensure that there is enough information to draw conclusions (Memon et al., 2020). The steps used to determine the number of samples are to calculate the number of samples. If the population is unknown, the Lemeshow formula is used for sampling. The sample calculation is carried out using the following formula[32].

$$n = \frac{Z^2 P(1-P)}{d^2}$$

Description:

N = Sample Size

Z= Significance level (1.96)

P= Estimated prevalence proportion in the population (0.0024)

d= Desired absolute density level (10%)

The minimum sample size that must be used if the confidence level is set at 95% and the Z value is 1.96. The sampling error is 10% or 0.10 and because the maximum estimated value is 0.0024, it can be calculated

$$n = \frac{Z^2 P(1-P)}{d^2}$$

$$n = \frac{(1,96)^2 \times 0,1(1-0,0024)}{(0,1)^2}$$

$$n = \frac{3,84 \times 0,1 \times 0,99}{0,01}$$

$$n = 38$$

Based on calculations using the Lemeshow formula, the number of samples in this study was 38 people.

Research Criteria

The researcher collected patient data, including information on clinical signs and symptoms (vomiting, lethargy, apnea, hypotension, abdominal distension, abdominal wall erythema, and rectal bleeding). The diagnosis of NEC was based on the modified Bell criteria. The criteria for respondents who would be used as research samples were as follows:

Inclusion criteria:

a. Infant patients with clinically confirmed NEC.

b. Infant patients who have undergone abdominal X-Ray examination.

c. Infant patients who have undergone USG examination

Exclusion criteria:

a. Infant patients with intra-abdominal bleeding.

b. Infant patients with clinical intra-abdominal tumors.

Research Instrument

The results of abdominal X-Ray and USG examinations on NEC patients that have been carried out at Dr. Hasan Sadikin General Hospital, Bandung from January 2023 – June 2024. The examination results were obtained from the Picture Archiving and Communication System (PACS) application, which is sophisticated hardware and software that functions as a digital image management system in various health institutions. Its main purpose is to enable radiologists and doctors to retrieve and view radiology images on computer workstations throughout the institution. PACS is an integrated electronic system used by the radiology department, which stores images electronically and displays them digitally throughout the hospital, even remotely, instead of relying on traditional film.40

How it Works

The method of this study is as follows:

1. The researcher submits a research proposal to the Medical Research Ethics Commission of the Faculty of Medicine, Padjadjaran University - Dr. Hasan Sadikin General Hospital, Bandung to obtain ethical clearance.

2. Determining subjects based on patient data from medical records.

3. All patients with NEC conditions who have undergone abdominal X-Ray and USG examinations at Dr. Hasan Sadikin General Hospital, Bandung from January 2023 - June 2024 who meet the specified inclusion criteria.

4. Retrieval of abdominal X-Ray and USG examination data through the PACS application.

5. The researcher writes the results of reading plain photos and USG in the research report.

Data Processing and Analysis

The steps in data processing are:

1. Data checking (Editing)

Data checking (Editing) is carried out to check the accuracy and completeness of the data that has been collected, if the data is incomplete or there are data errors.

2. Coding

Data coding is done when the data has been collected and then corrected for accuracy and completeness. Then the data is coded by the researcher manually before being processed into the computer.

3. Entering data (Entry).

The cleaned data is then entered into the computer program.

4. Data cleaning.

Checking all data that has been entered into the computer to avoid errors in data entry.

5. Saving data (Saving).

Data analysis was carried out to test the correlation between plain radiographs and ultrasound examinations in NEC conditions. If the data is normally distributed, then further testing is carried out using the parametric method, namely the Independent T-Test, while if the data is not normally distributed, then testing is carried out using the non-parametric method, namely the Mann Whitney Test. Data analysis was carried out using the assistance of the Statistical Product and Service Solution (SPSS) for Windows version 25.0 program at a confidence level of 95%.

Operational Definition

Research variables refer to characteristics or attributes that can be measured or observed and vary between people or organizations being studied. The variables in this study are the objects of research observation, in this case, namely the examination of NEC conditions using plain photo and USG methods.

Table 2 Operational Definition

Variable	Operational Definition	Measurement Methods and Tools	Measuring Scale
NEC	Necrotizing enterocolitis (NEC) is an inflammatory condition that can be assessed through pneumoperitoneum, ileus, free air and free fluid in the abdominal cavity.	Plain photo and USG	Categorical

Plain Photo	Plain abdominal radiographs are performed to assess the shape, size, wall thickness, degree of dilatation, portal vein air, pneumatosis and accumulation of free intra-abdominal fluid.	abdominal X-ray equipment unit	Categorical
USG	Abdominal USG is performed to assess the shape, size, wall thickness, degree of dilatation, portal vein air, pneumatosis and accumulation of free intra-abdominal fluid.	Ultrasound equipment unit	Categorical

Ethical Implications

This study was conducted after obtaining ethical clearance from the Research Ethics Committee of Padjajaran University, Bandung. In this study, 2 basic principles of human research ethics were applied, including:

1) Beneficience and non-maleficience (the principle of benefit and no harm): This study used a retroprospective method and was derived from primary data from observations, so that patients were not given treatment and therefore did not endanger the subjects.

2) Justice (the principle of confidentiality and justice): The selection of subjects was based on the inclusion and exclusion criteria that had been set, and did not violate the principle of justice.

3. Result and Discussion

This chapter contains a description and explanation of the results of data collection and processing. The discussion begins with a general description of the research subject, then continues with the analysis and interpretation of research data, and a discussion of the research results.

Description of Research Results

This study took NEC examination results data from the PACS application for the period January 2023 - June 2024 and obtained results from 39 patients. The data source for this study is secondary data obtained through an intermediary media, namely PACS. The secondary data source for this study is data that has been recorded at the Radiology Installation of Dr. Hasan Sadikin General Hospital, Bandung in the period January 2023 - June 2024. Researchers obtained results from 39 patients who met the inclusion criteria.

Plain Photo Examination Results

The plain photo examination results data for 39 patients who met the inclusion criteria were then described. The following are the results of the plain photo examination:

Table 4.1 Plain Photo Examination Results

Info	Normal	Grade I	Grade II	Grade IIA	Grade IIB	Grade IIIA	Grade IIIB
Total	5	27	5	1	-	1	-
%	12	69	12	2.5	0	2.5	0

The results of plain abdominal X-ray examination showed that 5 patients did not meet the criteria for establishing a diagnosis of NEC. A total of 27 patients were identified as having grade I NEC, with characteristics in the form of paralytic ileus without pneumatosis. A total of 5 patients were included in the grade II category and 1 patient in the IIA category with characteristics in the form of paralytic ileus accompanied by pneumatosis. Finally, 1 patient met the criteria for grade IIIA, in the form of paralytic ileus, pneumatosis, portal venous gas, and pneumoperitoneum.

Results of Ultrasound Examination

The data from the results of plain abdominal X-ray examination of 39 patients who met the inclusion criteria were then described. The following are the results of the ultrasound examination:

Table 4.2 Results of Ultrasound Examination

Info	Normal	Grade I	Grade II	Grade IIA	Grade IIB	Grade IIIA	Grade IIIB
Total	0	22	2	7	4	4	-
%	0	56.4	5.1	17.9	10.2	10.2	0

The results of plain abdominal X-ray examination showed that 22 patients were identified as having NEC grade I, with characteristics in the form of paralytic ileus without pneumatosis. A total of 2 patients were in the grade II category and 7 patients in the IIA category with characteristics in the form of paralytic ileus accompanied by pneumatosis. A total of 4 patients met the criteria for grade IIIA in the form of paralytic ileus, pneumatosis, portal venous gas, and pneumoperitoneum.

Results of Correlation of Plain abdominal X-Ray and USG Examination

The researcher compared the results of plain abdominal X-ray and USG examinations to see how the correlation between the two examinations. The following are the results of plain abdominal X-ray and USG examinations obtained by the researcher:

Table 4.3 Results of Plain abdominal X-Ray and USG Examination

No	Plain abdominal X-ray Diagnosis	Ultrasound Diagnosis	Info
1	Grade I	Grade I	Stay
2	Grade II	Grade IIA	Up
3	Grade II	Grade IIA	Up
4	Normal	Grade I	Up
5	Grade I	Grade I	Stay
6	Normal	Grade I	Up
7	Grade I	Grade II	Up
8	Grade I	Grade I	Stay
9	Grade I	Grade I	Stay
10	Grade I	Grade I	Stay

11	Grade I	Grade IIB	Up
12	Grade I	Grade IIB	Up
13	Grade I	Grade I	Stay
14	Grade I	Grade IIB	Up
15	Grade I	Grade I	Stay
16	Grade I	Grade I	Stay
17	Grade I	Grade I	Stay
18	Grade I	Grade I	Stay
19	Grade I	Grade I	Stay
20	Grade II	Grade II	Stay
21	Grade I	Grade IIIA	Up
22	Grade I	Grade I	Stay
23	Grade IIA	Grade IIA	Stay
24	Grade I	Grade I	Stay
25	Grade I	Grade IIA	Up
26	Grade I	Grade IIA	Up
27	Grade I	Grade I	Stay
28	Grade I	Grade IIIA	Up
29	Grade I	Grade IIIA	Up
30	Grade I	Grade IIA	Up
31	Grade III	Grade IIB	Down
32	Grade I	Grade I	Stay
33	Grade I	Grade IIIA	Up
34	Grade II	Grade IIA	Up
35	Grade I	Grade I	Stay
36	Grade I	Grade I	Stay
37	Grade I	Grade I	Stay
38	Normal	Grade I	Up
39	Grade II	Grade I	Down

Based on the research data above, the researcher found that as many as 20 patients had a consistent diagnosis between plain abdominal X-ray and USG examinations. Second, the researcher found that as many as 17 patients experienced an increase in grade on USG examinations. Finally, as many as 2 patients experienced a decrease in grade.

Data Analysis Results

The data obtained were then processed using the Spearman test, which is a statistical procedure used to see if there is a correlation between two variables. If the significance value is <0.05, the two variables are said to be correlated.

Table 4.4 Spearman Test Results

			Fotopolos	USG
Spearman's rho	Plain Photo	Correlation Coefficient	1.000	.242
		Sig. (2-tailed)	.	.138
		N	39	39
	USG	Correlation Coefficient	.242	1.000
		Sig. (2-tailed)	.138	.
		N	39	39

Based on the data above, it can be seen that the significance value obtained is 0.138, or greater than 0.05. so it can be concluded that the results of plain abdominal X-ray and USG examinations in NEC conditions do not have a correlation.

Discussion

The purpose of this study was to test and analyze the correlation of NEC examinations using plain abdominal X-rays and USG. The sample in this study was 39 patients who experienced NEC at Dr. Hasan Sadikin General Hospital, Bandung in the period January 2023-June 2024. NEC is a non-specific inflammatory condition caused by infectious agents with a background of immaturity of local defense mechanisms and hypoxic-ischemic damage to the intestinal mucosa. NEC is one of the gastrointestinal disorders that attacks premature babies and is the main cause of emergency surgery in the neonatal intensive care unit (NICU).[2,3,4]

NEC is one of the feared diseases because it occurs most often in premature babies and has a mortality rate of 30-40%. In the absence of a specific test, the 1978 Bell staging system remains an important diagnostic tool in clinics and in research. This staging system relies on abdominal, systemic, and radiographic signs, allowing cases to be divided into three stages. [7,8,44]

Based on previous research conducted by Espasito et al (2017), clinical symptoms of NEC are often not specific. Imaging plays an important role in determining the timing of diagnosis. Plain abdominal radiographs remain the primary and most frequently used modality in the evaluation and monitoring of NEC. Unfortunately, some radiographic signs may appear in advanced stages of the disease when wall damage has consolidated, requiring additional examinations such as ultrasound. In recent years, ultrasound has played an increasingly important role in the evaluationof early stages of the disease because it provides direct and real-time images of abdominal structures that are able to assess the presence and validity of intestinal loop peristalsis, detect intestinal wall thickness and the presence of small amounts of fluid in the abdominal cavity. [2]

This study used secondary data obtained through the PACS application, and obtained 39 patients. Based on plain radiographs, 12% of patients were in the normal category, or the diagnosis could not be established for NEC. As many as 69% experienced NEC in the grade I category. As many as 69% were in the grade II category, 2.5% were in the IIA category, and finally 2.5% were in the IIIA category.

Common symptoms of NEC include abdominal distension and food intolerance, ileus, which can develop into discoloration of the abdominal wall, bile aspiration, and hematochezia. In the research data, it was found that patients included in the grade I category experienced paralytic ileus without insentinalis pneumatosis. In the grade II category, the condition was accompanied by insentinalis pneumatosis, while in grade IIIA, conditions were found in the form of paralytic ileus, insentinalis pneumatosis, portal venous gas, and pneumoperitoneum.

Based on the results of the examination using USG, the researchers found that as many as 20 patients had a consistent diagnosis between plain abdominal X-ray and USG examinations. The researchers also found that as many as 17 patients experienced an increase in grade on USG examinations. This condition can be explained by the diagnostic imaging of the neonatal gastrointestinal tract has relatively limited accuracy, and limits improvements in diagnostic efforts and severity measurements. The sensitivity of the radiographic approach has been limited to 55-60% of all patients. USG can help evaluate and identify NEC conditions. USG provides a real-time picture of the condition and is more sensitive to see NEC symptoms. Based on this explanation, it can be concluded that the increase in NEC grade categorization on USG examinations occurs because

the sensitivity of USG allows for more detailed viewing. 2,3,11 The data from the plain abdominal X-ray and USG examinations were then tested for correlation using the Spearman test. Based on this test, it was found that the results of the plain abdominal X-ray and USG examinations did not correlate, with a significance value of 0.138 or greater than 0.05, so the hypothesis of this study was rejected. The findings that can be taken from this study are that there was an increase in grade in patients who underwent USG examinations. This finding proves the importance of performing an ultrasound examination to confirm NEC conditions more accurately.

The diagnosis and management of NEC remain challenging due to the lack of objective imaging methods for early detection with adequate sensitivity and specificity. The use of traditional abdominal radiography for the diagnosis of NEC has poor specificity, leads to ambiguity in differentiating it from similar conditions, and can lead to failure of early detection. By the time specific diagnostic features become apparent, NEC has progressed to an advanced, irreversible stage. Recent advances in this field have identified ultrasound as a viable alternative with the potential for earlier diagnosis, improved management, and improved prognosis for premature infants with NEC. This explanation is consistent with the results of studies showing that ultrasound examination methods are more sensitive in detecting symptoms of NEC that are not visible on plain radiographs. 11 Currently, ultrasound is still not used routinely for diagnosis and follow-up. The main advantages of abdominal ultrasound over plain radiographs are that it can depict intra-abdominal fluid, bowel wall thickness, and bowel wall perfusion. Ultrasound can depict consistent changes compared to nonspecific and inconclusive findings on plain radiographs. Bowel wall thinning and poor perfusion on USG strongly suggest nonviable bowel and may be seen before visualization of pneumoperitoneum on plain abdominal radiography. Mortality is higher after perforation; therefore, early detection of severely ischemic or necrotic bowel loops, before perforation occurs, has the potential to improve morbidity and mortality in NEC. The information provided by USG allows a more complete understanding of the bowel condition in patients with NEC and may thus facilitate management decisions and potentially change outcomes.41

Plain abdominal X-ray remains the primary diagnostic tool in the diagnosis and follow-up of NEC. However, it is sometimes not possible to expose patients to consecutive episodes of radiation. USG appears to be an alternative to the current standard radiography. USG is an ideal modality for evaluating bowel necrosis because it is noninvasive, does not involve the use of ionizing radiation, and can be easily performed at the bedside.42,43

4. Conclusion

Based on the research that has been conducted, it can be concluded that:

1. The results of the correlation test found that there was no significant correlation between the plain abdominal X-ray and USG examination procedures.

2. Examination using the USG method is more sensitive so that it can see the NEC condition more accurately, this is proven by the increase in grade in patients.

Suggestions

As a follow-up to the results of the research and trials that have been conducted, several suggestions are proposed as follows:

1. The results of this study are expected to be additional information regarding radiological examinations in NEC conditions using the plain abdominal X-ray and USG methods.

2. For further research, it is necessary to complete more detailed demographic data to enrich the research data.

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