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Uslu-Kızılkan N *et al.* MII- pH monitoring *vs* reflux scintigraphy

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**Abstract**

***AIM***

To evaluate the agreement of multichannel intraluminal impedance-pH monitoring (MII-pHM) and gastroesophageal reflux scintigraphy (GES) for diagnosis of gastroesophageal reflux disease.

***METHODS***

Seventyfive consecutive patients with suspected gastroesophageal reflux disease (GERD) underwent 24-hour combined MII-pHM recording and one hour radionuclide scintigraphy during the course of MII-pHM study. Catheters with 6 impedance channels and 1 pH sensor were placed transnasally. Impedance and pH data analysis were performed automatically and also manually. For impedance monitoring reflux was defined as a retrograde 50% drop in impedance, starting distally and propagating retrogradely to at least next two more proximal measuring channels. Reflux index (RI, percentage of the entire record that esophageal pH is < 4.0) greater than 4.2% for pHM, number of refluxes for 24 h more than 50 for MII were accepted as positive test results. At scintigraphy, 240 frames of 15 s duration were acquired in supine position. Gastroesopahgeal reflux was defined as at least one reflux episode in the esophagus. After scintigraphic evaluation, impedance-pH recordings and scintigraphic images were evaluated together and agreement between tests were evaluated with Cohen’s kappa.

***RESULTS***

Sufficient data was obtained from 60 (80%) patients (34 male, 56.7%) with a mean age of 8.7 ± 3.7 years (range: 2.5-17.3 years; median: 8.5 years). Chronic cough, nausea, regurgitation and vomiting were the most frequent symptoms. The mean time for recording of MII-pHM was 22.8 ± 2.4 h (range: 16-30 h; median: 22.7 h). At least one test was positive in 57 (95%) patients. According to diagnostic criteria, GERD was diagnosed in 34 (57.7%), 44 (73.3%), 47 (78.3%) and 51 (85%) patients by means of pHM, MII, GES and MII-pHM, respectively. The observed percentage agreements/κ values for GES and pHM, GES and MII, GES and MII-pHM, and MII and pHM are 48.3%/-0.118; 61.7%/-0.042; 73.3%/0.116 and 60%/0.147, respectively. There was no or slight agreement between GES and pHM alone, MII alone or MII-pHM. pH monitoring alone missed 17 patients compared to combined MII-pHM. Addition of MII to pH monitoring increased the diagnosis rate by 50%.

***CONCLUSION***

No or slight agreement was found among pH monitoring, MII monitoring, MII-pH monitoring and GES for diagnosis of gastroesophageal reflux disease.

**Key words:** Gastroesophageal reflux disease; Children; Multichannel intraluminal impedance; Esophageal pH monitoring; Scintigraphy

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**Core tip:** Gastroesophageal reflux (GER) is usually physiologic and common in childhood, and is defined as GER disease (GERD) when it causes troublesome symptoms and/or complications. Unfortunately, the ideal diagnostic method for GERD has not been identified yet. Each method has its own advantages and disadvantages. The study aimed to evaluate the agreement of multichannel intraluminal impedance-pH monitoring and gastroesophageal reflux scintigraphy, which is used frequently all over the world for the diagnosis of GERD. No or slight agreement between tests was found. New diagnostic standards for scintigraphy in GERD should be defined.

Uslu Kızılkan N, Bozkurt MF, Saltık Temizel IN, Demir H, Yüce A, Caner B, Özen H.

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**INTRODUCTION**

Gastroesophageal reflux (GER) is defined as passage of gastric contents into the esophagus which is usually physiologic and common in childhood[1]. It is defined as gastroesophageal reflux disease (GERD) when it causes troublesome symptoms and/or complications. It is important to distinguish physiologic GER events from GERD. A variety of tests for the diagnosis of GERD are available; 24-hour esophageal pH monitoring (pHM), multichannel esophageal intraluminal impedance testing (MII), combined MII and pHM (MII-pHM), gastroesophageal reflux scintigraphy (GES), upper gastrointestinal barium contrast radiography, esophagoscopy and biopsy, motility studies and ultrasonography[1,2]. Each of these tests for diagnosis of GERD in the pediatric population has advantages and limitations, and none of them is ideal. In children old enough to describe their symptoms reliably, the diagnosis of GERD can be made clinically and it is generally not necessary to perform diagnostic tests.

MII-pHM detects acid, weakly acid, and nonacid reflux episodes, can detect accurately the height of the refluxate, is able to determine whether the refluxate is liquid, gas, or mixed (both liquid and gas), can still measure symptom association with GER even while the patient is taking acid-suppression medications and is superior to pH monitoring alone for evaluation of the temporal relation between symptoms and GER. However, MII/pHM is expensive and time consuming[1,310]. Additionally, the specificity of automated analysis (AA) is low and inter- and intraobserver variability is large and agreement with automated analysis is poor[11-13]. Manual analysis may take 3 h depending on the experience of the investigator and the number of reflux episodes to be analyzed. Another limitation of MII-pHM use is that it is not commonly available and normal values for all of the age groups have not yet been established[5-9]. Despite these limitations studies in the last decade revealed that this method can be the golden diagnostic method for GER detection[14].

Nuclear imaging scintigraphy is more widely available worldwide than pHM and/or MII-pHM. It is simple, noninvasive, can detect not only reflux event but also aspiration, abnormal esophageal contractions and delayed gastric emptying, and takes mostly one hour to perform the procedure and accepted by many pediatricians as an additional diagnostic test for the diagnosis and follow-up of GER in infants and children. It also allows to quantify gastric emptying and to detect reflux aspiration into bronchial system. Also it has some disadvantages as performance and interpretation of the test can show some variations between centres as the standards of the test is poorly established. Showing only postprandial refluxes independent of pH lowers its diagnostic value as it is already known that GER occurs mostly in postprandial period[15-22]. The European (ESPGHAN) and North American (NASPGHAN) Societies for Pediatric Gastroenterology, Hepatology, and Nutrition do not recommend GES in the routine diagnosis and management of GER in infants and children because of the low sensitivity of the test[1].

The primary aim of the study is to evaluate the agreement of GES, which is used frequently all over the world for the diagnosis of GERD and MII-pH monitoring. We also aimed to investigate the sensitivity and specificity of pHM alone and GES compared to MII-pHM and vice versa.

**MATERIALS AND METHODS**

***Patient population***

Seventyfive consecutive patients referred to Hacettepe University Pediatric Gastroenterology, Hepatology and Nutrition Unit for suspected GERD were enrolled in the study. Patients younger than 24 mo were excluded.

***Multichannel intraluminal impedance-pH monitoring***

All patients underwent 24-hour combined MII-pHM recording (MMS Ohmega Ambulatory Impedance and pH Recorder, Netherland). All of the subjects had been taken off proton pump inhibitors, histamine-receptor antagonists and prokinetics at least 72 h before the study. Impedance catheters with 7 impedance (6 channels) and 1 pH sensors (Unisensor, Attinkon, Switzerland} were used. pH sensor was placed at 3rd cm while impedance sensors were placed at 1-3-5-7-9-11-13 cm. Before the procedure, the pH recorder was calibrated using buffered solutions of pH 1.0 and pH 7.0 as specified by the manufacturer. The catheter was placed through the nose and the pH sensor was placed at 87% of the nares-lower esophageal sphincter distance[23]. Placement of pH sensor was confirmed by radiographic evaluation. The catheter was connected to a data logger which stores data from impedance channels with a frequency of 50 Hz and pH sensor of 1 Hz. Children received their regular diets except acidic drinks and were asked to keep at least 4 h intervals between the meals.

Impedance and pH data analysis were performed automatically by using MMS Investigation and Diagnostic Software®, Netherlands. All tracings were also manually reviewed by investigators (HÖ, NUK) experienced in interpretation of pH-impedance recording. For impedance monitoring reflux was defined as a retrograde 50% drop in impedance, starting distally and propagating retrogradely to at least next two more proximal measuring channels[24]. A GER episode was then defined as acidic (pH < 4), weakly acidic (pH between 4 and 7) or alkaline (pH > 7) according to the associated pH change. Physical composition of the refluxate was also identified, and MII detected episodes were divided into liquid, and mixed. Reflux index (RI, percentage of the entire record that esophageal pH is < 4.0) greater than 4.2% for pHM, number of refluxes for 24 h more than 50 for MII were accepted as positive test results[24-28]

***Gastroesophageal reflux scintigraphy***

The scintigraphy was performed during the course of MII-pH study after a fasting of 4 h using technetium-99m tin colloid (7 microCi/kg body weight or 0.74 megabecquerel/kg bw, minimum dosage 200 microCi and maximum dosage 500 microCi) administered orally in a mixture of thick orange juice for patients older than 3 years and milk or formula (20 mL/kg body weight, maximum 300 mL). After swallowing 30 ml of radiolabeled test liquid, the patient was given the remaining portion of unlabeled orange juice or milk/formula. Patients lied in supine position under the gamma camera for 1 h and kept immobile with velcro straps. Two hundred and forty frames of 15 s duration were acquired in a 64 × 64 matrix. At the beginning of scintigraphy the time showed by ambulatory impedance-pH recorder was recorded. All results were visually analyzed for the occurrence of reflux by two investigators (MFB, BC). No quantitative analysis was performed. Gastroesopahgeal reflux was defined as at least one reflux episode in the esophagus defined as linear activity emerging from stomach to esophageal trajectory in dynamic scintigraphic imaging[15].

After scintigraphic evaluation, impedance-pH recordings and scintigraphic images were evaluated together (NUK, HÖ, MFB, BC) and agreement among three tests were recorded.

***Ethical permission***

Hacettepe University Clinical Researches Ethics Board approved the study (B.30.2.HAC.0.01.00.05/222). Written consent was obtained from all of the parents and patients old enough to understand and sign the informed assent form.

***Statistical analysis***

Parametric data are presented as mean ± SD unless otherwise stated. Agreement betwen tests for diagnosis of GERD was assessed by using Cohen’s kappa (κ)[29];values ≤ 0 indicates no agreement, 0–0.20 slight agreement, 0.21–0.40 fair agreement, 0.41–0.60 moderate agreement, 0.61–0.80 substantial agreement, and 0.81–1 almost perfect agreement. Overall percent agreement, positive (PPA) and negative (NPA) percent agreements are calculated where they are needed. Sensitivity, specificity, positive and negative predictive values of the tests also calculated according to the considered gold standard diagnostic method (MII-pHM or GES). Statistical significance was defined as *P* < 0.05. SPSS version 16 was used for statistical analysis. The statistical methods of this study were reviewed by Prof.Ergun Karaagaoglu from Department of Biostatistics, Hacettepe University Faculty of Medicine.

**RESULTS**

Seventy-five children were enrolled in the study. The duration of patients’ symptoms regarding GER was 10.8 ± 9.9 mo (range: 1-48 mo; median: 8.0 mo). Chronic cough, nausea, regurgitation and vomiting were the most frequent symptoms.

The tests were well tolerated by all of them without any complications. Fourteen patients were excluded for artifacts and technical problems in MII-pH tracings (eight non-interpretable traces due to artifacts or displacement of the probe; four for technical reasons; and two premature termination of the recording due to battery problems), and one patient because of unsuccessful scintigraphic procedure. Sufficient data was obtained from 60 (80%) patients (34 male, 56.7%) with a mean age of 8.7 ± 3.7 years (range: 2.5-17.3 years; median: 8.5 years). The mean time for recording of MII-pHM was 22.8 ± 2.4 h (range: 16-30 h; median: 22.7 h).

At least one test was positive in 57 (95%) patients, and three patients had negative results for all of the tests. Eighteen patients (30%) had positive test results for all three tests, while 30 (50%) patients had positive results for 2 of the tests and 9 (15%) had positive results for only 1 test. According to mentioned criteria above, gastroesophageal reflux disease was diagnosed in 34 (57.7%), 44 (73.3%), 47 (78.3%) and 51 (85%) patients by means of pHM, MII, GES and MII-pHM, respectively.

The mean reflux index was 6.0% ± 6.9% (range 0.1-38.4), and mean reflux number 70.6 ± 83.4 (range 6-481) with pH monitoring. The mean number of reflux episodes > 5 min was 2.2 ± 3.3 (range, 0-19). Overall, 3.879 (mean 64.6 ± 29.8, range: 18-146) GER events were detected with MII monitoring (liquid 1169, 30.1% and mixed 2710, 69.9%), and 1751 (45.1%) of them were characterized as acidic, 1618 (41.7%) as weakly acidic and 510 (13.2%) as alkaline. Also we observed that 32.9% of refluxes reached proximal esophagus and 41.2% of them were nonacidic.

During 1 hour simultaneous recording period 880 reflux episodes were detected with GES and/or MII-pHM. GES showed 770 reflux frames in 47 patients, only 142 of them (18.4%) were detected simultaneously with both techniques. Six hundred and twenty-eight episodes were detected only with GES, and 110 only with MII-pHM (kappa = -0.27, *P* < 0.0001).

Table 1, 2, 3, and 4 show comparisons of GES and pHM, GES and MII, GES and MII-pHM, MII and pHM, respectively. The observed percentage agreements/κ values for above comparisons are 48.3%/-0.118; 61.7%/-0.042; 73.3%/0.116 and 60%/0.147, respectively. pH monitoring alone missed 17 patients compared to combined MII-pHM. Therefore, addition of MII to pH monitoring increased the diagnosis rate by 50%.

Assuming MII+pH monitoring or GES as gold standard for GER diagnosis sensitivity, specifity, positive and negative predictive values for pHM, MII, MII-pHM, and GES are shown in Table 5.

**DISCUSSION**

Gastroesophageal reflux is a common, challenging problem for pediatricians. It is important to differentiate physiologic GER from GERD, which may cause severe complications, to decide who needs treatment[1]. Both pHM[30,31] and radionuclide[32] studies for diagnosis of GERD go back more than 40 years. Esophageal intraluminal pHM became more popular with the development of computer based system for the recording and automatic analysis of the data[33], and was accepted as gold standard for diagnosis of GERD for years. Later on MII has been developed and posited as the future standard for reflux detection and monitoring[34]. Although the combined MII-pHM has advantage over pHM alone, it has some disadvantages mentioned above[1,4,11,14,35].

Another problem with pHM and MII is the absence of normal values in the pediatric age range. Currently no evidence based pediatric normal values exist for them. The ESPGHAN and NASPGHAN guidelines consider a RI > 7% as abnormal, a RI < 3% as normal, and between 3% and 7% as indeterminate[1]. In this study a RI value > 4.2% was accepted as abnormal[27,36]. Presently, the “true” normal ranges for MII are not available for infants and children due to the fact that it is not ethical to perform MII-pHM on asymptomatic, healthy children. In children referred for GERD evaluation, the mean retrograde bolus movement numbers were reported as between 31 and 35, respectively[27]. But, all were sick children and they do not represent the healthy children. The reported number of reflux events (95th percentile) in healthy adults ranged from 48 to 75 per day, and the age did not affect the number[24,26,28]. In healthy adults consuming Mediterranean diet the total numbers of reflux events was 48 (95th percentile)[26] and we arbitrarily defined the upper limit as 50 reflux per day.

The literature shows an extremely poor correlation between acid reflux measured with pHM and reflux episodes detected with scintigraphy Although there are many studies reviewing the diagnostic methods, studies comparing GES and pHM, MII or MII-pHM are scarce.

Vandenplas et al compared the information provided by pHM and GES which were performed in 65 children investigated for suspected GERD[37]. During 1 hour simultaneous-recording period 123 reflux episodes were recorded with both techniques, but only six (4.9%) of them occurred simultaneously. Another study comparing results of scintigraphy and pHM showed that both methods concurrently detected only 42% reflux episodes[38]. In our study, 142 (16.1%) of 880 reflux episodes were observed with both GES and MII/pHM. The reasons for this low concordance can be due to a few factors; 1-Scintigraphy may show inadequate esophageal clearance or remnants or refluxes, that can not be shown with MII-pHM. 2-pH monitoring can not be able to detect non acidic refluxes. 3-All reflux episodes may not propagate to at least 2 impedance channels. 4-Additionally, frame acquisition technique may also affect the detection rate of GER events[17,37-39].

Studies found sensitivity and specificity for GES between 15-59% and 83-100%, respectively,when compared with 24-hour esophageal pHM[38,40-44]. In our study, the sensitivity of GES was higher than its specificity, different from previous studies, and comparing the results of pHM and GES showed that two tests were in agreement for 29 (48.3%) patients and kappa value is below zero. If pHM is considered as reference test, PPA is 73.5% while NPA is 15.4%. For MII 61.7% of the patients had positive results for both MII and GES and the results seemed to be more comparable than pHM but kappa value is not still significant. For MII-pHM kappa is close to zero, overall percent fo agreement is 73.3% and, similar to the comparison with pHM and MII, PPA is much higher than NPA. These findings may be due to that GES shows only postprandial reflux events and even 1 episode is accepted as a positive result. As there are not similar studies we couldn’t compare our results.

In an article evaluating 2178 studies[45], 6 of them containing 408 participtants were included, it was concluded that diagnostic accuracy of tests in children suspected of GERD is unclear. In these studies the sensitivity of pHM ranged from 41%-81%. pH monitoring can only detect acidic (pH < 4) episodes and underestimate postprandial refluxes which most GER occurs in postprandial periods particularly in infants[39]. Shay *et al*[46] evaluated 19 GERD patients with manometry, pHM and MII simultaneously for 2 h and found that only 19% of the refluxes could be detected by all three methods. By MII study more refluxes were detected comparing manometry and pHM (96% *vs* 76% and 28%, respectively) and also 15% of refluxes were detected only by MII monitoring. In a study published in 2005[47], 70 GER patients underwent various tests, including esophagogastroduodenoscopy with biopsy from the lower esophageal mucosa during the first visit, followed by omeprazole challenge test (OCT), radionuclide scintigraphy, barium swallow and finally 24-h esophageal pHM. A positive concordance of three or more tests was taken as the gold standard. As a single diagnostic test, pHM had the best combination of sensitivity and specificity (77.7% and 92%) while the values for scintigraphy were 15.5% and 96%.

In our study GERD was diagnosed in 34 (57.7%), 44 (73.3%), 47 (78.3%) and 51 (85%) patients by pHM, MII, GES and MII/pHM, respectively. pHM shows the lowest positive results and MII-pHM shows that 54.9% of refluxes were nonacidic so by evaluation only pHM some patients should not be diagnosed.

About 70% of reflux epidodes occur during feeding and the first 2 postprandial hours and the remaining episodes occur during the remaining time until the next feeding[5]. This is specially important for patients with pulmonary symptoms as sentenced in some studies[48]. Dalby *et al*[49] stated that MII/pHM can detect all refluxes (acidic/nonacidic), content of the refluxes, association of symptoms and reflux episodes with high reproducibility. By the addition of MII in our study, the number patients daignosed as having GERD increased by 50%.

Our results show that MII-pHM is more sensitive comparing with GES and pHM. When MII-pHM or GES is considered as gold standard test, sensitivities of GES and MII-pHM are above 80%. But, negative predictive value and NPA are low, ranging from 23.1% to 33.3%. This may be due to that reflux even in one frame was accepted as a positive result. Clinical significance of number of episodes and intensity of the reflux events has not been clearly documented. In one study it was stated that increasing episode number in GES might be a predictor for reflux-related symptom severity[50].

Our results demonstrate that there is slight or no agreement between MII/pH monitoring and GES results. Especially the compatibilitiy is weaker for negative results. MII-pHM showed better results than other tests for sensitivity and positive predictivity.

We recognize that this study has limitations. Absence of asymptomatic control children limits our ability to infer any clinical relevance, but because of ethical reasons we did not obtain a control study group. Also normal values for children for MII-pH monitoring have not been established so the results have been compared with those described in few studies and the results might have changed with different cut-off values. Patient selection may have an impact on the prevalence of GER in patients as we studied a heterogeneous group in age and symptomps including both subjects with and without typical GER symptoms. It would be valuable to check if the test results were correlated with different patterns or severity of complaints, but it was not the aim of the study. Additionally, we did not accept one test as gold standard. As far as we know this is the first study to compare MII-pHM and GES.

In conclusion, the most sensitive test for diagnosing GERD is MII-pHM. No or slight agreement was found between pHM, MII, MII-pHM and GES for diagnosis of GERD. Scintigraphy should be interpreted carefully and efforts should be aimed to develop new diagnostic standards for scintigraphy in GERD.One must keep in mind that negative results donot mean that the patient does not have GERD while one reflux episode may represent a physiologic postprandial reflux. Also standardization and new diagnositic criterias need to be evalutaed for scintigraphy. With the use of new techniques for the diagnosis some questions are answered as well as some questions are arising and the ideal diagnostic test for GERD has not been identified yet.

**COMMENTS**

***Background***

It is important to distinguish physiologic gastroesophageal reflux (GER) events from GER disease (GERD). Currently, multichannel intraluminal impedance-pH monitoring (MII-pHM) is accepted as gold standard for diagnosis of GERD, but it is expensive and is not commonly available and normal values for all of the age groups have not yet been established.

***Research frontiers***

Gastroesophageal reflux scintigraphy (GES) is easy to perform and more widely available worldwide than MII-pHM. Although there are many studies reviewing the diagnostic methods, studies comparing GES and pHM, MII or MII-pHM are scarce.

***Innovations and breakthroughs***

This study evaluated the agreement of GES and MII-pH monitoring and showed a slight or no agreement between reflux measured with MII-pHM and reflux episodes detected with scintigraphy.

***Applications***

These results show that MII-pHM is more sensitive comparing with GES. Scintigraphy should be interpreted carefully and efforts should be aimed to develop new diagnostic standards for scintigraphy in GERD.

***Terminology***

Impedance testing is based on changes in electrical resistance between two rings produced by the presence of bolus inside the esophageal lumen. Decrease in resistance indicates the presence of a liquid bolus. Impedance catheters have multiple sets of impedance-measuring rings and can assess bolus movement and direction. GES involves the oral administration of a radiopharmaceutical followed by scintiscanning of the stomach and esophagus to detect reflux events during the recording session.

***Peer-review***

In the paper “Comparison of multichannel intraluminal impedance-pH monitoring and reflux scintigraphy in pediatric patients with suspected gastroesophageal reflux”, Uslu-Kizilkan *et al* present a very interesting and diligently performed study on gastroesophageal reflux, primarily comparing a pH- and impedance-detection dependant with a scintigraphic method in a prospective, comparative way, analysing patients with both methods, and comparing the results.

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**Table 1 Comparison of pH monitoring and gastroesophageal reflux scintigraphy**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Gastroesophageal scintigraphy positive | Gastroesophageal scintigraphy negative | Total |
| pH monitoring positive | 25 | 9 | 34 |
| pH monitoring negative | 22 | 4 | 26 |
| Total | 47 | 13 | 60 |

Kappa value= -0.118 [*P* = 0.302, 95%CI: -0.232-(-0.004)]; Overall percent agreement = 48.3%; When pH monitoring is considered as reference test; positive percent agreement = 73.5% and negative percent agreement = 15.4%.

**Table 2 Comparison of multichannel intraluminal impedance monitoring and gastroesophageal reflux scintigraphy**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Gastroesophageal scintigraphy positive | Gastroesophageal scintigraphy negative | Total |
| MII monitoring positive | 34 | 10 | 44 |
| MII monitoring negative | 13 | 3 | 16 |
| Total | 47 | 13 | 60 |

Kappa value = -0.042 (*P* = 0.741, 95%CI: -0.17-0.086); Overall percent agreement = 61.7%; When MII monitoring is considered as reference test; positive percent agreement = 77.3% and negative percent agreement = 18.8%. MII: Multichannel intraluminal impedance.

**Table 3 Comparison of multichannel intraluminal impedance/** **pH monitoring and gastroesophageal reflux scintigraphy**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Gastroesophageal scintigraphy positive | Gastroesophageal scintigraphy negative | Total |
| MII-pHM positive | 41 | 10 | 51 |
| MII-pHM negative | 6 | 3 | 9 |
| Total | 47 | 13 | 60 |

Kappa value 0.116 (*P* = 0.357, 95%CI: -0.01 - 0.24); Overall percent agreement = 73.3%;

When MII-pHM is considered as reference test; positive percent agreement = 80.4% and negative percent agreement = 33.3%. MII-pHM: Multichannel intraluminal impedance-pH monitoring.

**Table 4 Comparison of multichannel intraluminal impedance and pH monitoring**

|  |  |  |  |
| --- | --- | --- | --- |
|  | pH monitoring positive | pH monitoring negative | Total |
| MII monitoring positive | 27 | 17 | 44 |
| MII monitoring negative | 7 | 9 | 16 |
| Total | 34 | 26 | 60 |

Kappa = 0.147 (*P* = 0.223, 95%CI: 0.026-0.268). Overall percent agreement = 60%; MII: Multichannel intraluminal impedance.

**Table 5 Sensitivity, specificity, positive and negative predictive values of diagnostic tests according to assumed (considered) gold** **standard test**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Gold standard | | | | | | | |
| Test | **MII-pH monitoring** | | | | **GES** | | | |
| **Sensitivity%**  **(95%CI)** | **Specificity%**  **(95%CI)** | **PPV%**  **(95%CI)** | **NPV%**  **(95%CI)** | **Sensitivity%**  **(95%CI)** | **Specificity%**  **(95%CI)** | **PPV%**  **(95%CI)** | **NPV%**  **(95%CI)** |
| MII-pHM | - | - | - | - | 87.2  (73.6-94.7) | 23.1  (6.2-54.0) | 80.4  (66.5-89.7) | 33.3  (9.0-69.1) |
| pHM alone | 66.7  (52.0-78.9) | 100.0  (62.9-100.0) | 100.0  (87.4-100.0) | 34.6  (17.9-55.6) | 53.2  (38.2-67.6) | 30.8  (10.4-61.1) | 73.5  (55.3-86.5) | 15.4  (5.0-35.7) |
| MII alone | 73.3  (73.1-93.8) | 100.0  (62.9-100.0) | 100.0  (90.0-100.0) | 56.3  (30.6-79.2) | 72.3  (57.1-83.9) | 23.1  (6.0-54.0) | 77.3  (61.8-88.0) | 18.6  (5.0-46.3) |
| GES | 80.4  (66.5-89.7) | 33.3  (9.0-69.1) | 87.2  (73.6-94.7) | 23.1  (6.1-54.0) | - | - | - | - |

GES: Gastroesophageal scintigraphy; MII-pHM: Multichannel intraluminal impedance-pH monitoring; pHM: Esophageal pH monitoring; MII: Multichannel intraluminal impedance monitoring; 95% CI: 95% confidence interval; PPV: Positive predictive value; NPV: Negative predictive value.