



Inguinal Hernia in Preterm Infants: Optimal Timing of Herniorrhaphy to Prevent Preoperative Incarceration and Postoperative Apnea

Jaeho Shin, MD¹ and Ga Won Jeon, MD, PhD²

¹Division of Pediatric Surgery, Department of Surgery, Inje University Busan Paik Hospital, Busan, Korea

²Department of Pediatrics, Inje University Busan Paik Hospital, Inje University College of Medicine, Busan, Korea

ABSTRACT

Purpose: The objective of this study was to determine the optimal timing of inguinal herniorrhaphy in preterm infants to reduce the risks of preoperative incarceration and postoperative complications.

Methods: Preterm infants with gestational age (GA) of <37 weeks who had inguinal herniorrhaphy before the age of 6 months were enrolled. Early repair was defined as undergoing herniorrhaphy before discharge from the neonatal intensive care unit (NICU), and late repair was defined as undergoing herniorrhaphy as an outpatient after discharge from the NICU.

Results: The incidence rates of preoperative incarceration and recurrence were not significantly different between the two groups. Postoperative apnea and mechanical ventilation were more frequent in the early-repair group than in the late-repair group. Postoperative apnea was more frequent in the early-repair group after adjustments for GA and birth weight. However, no significant difference in postoperative mechanical ventilation was found between the two groups after adjustments for GA and birth weight. The incidence of postoperative apnea was associated with small weight at repair, early repair, general anesthesia, younger GA, small weight at birth, and bronchopulmonary dysplasia. Contralateral metachronous hernia was most frequent in infants with small weight at repair, early repair, very low birth weight (VLBW), male sex, and right-sided hernia.

Conclusion: Late repair was safe and did not increase the risk of incarceration or recurrence, but decreased the risks of postoperative apnea and metachronous hernia. Regional anesthesia could reduce the risk of postoperative apnea. Male infants born with VLBWs and right-sided hernia should be followed up carefully for metachronous hernia.

Key Words: Infant, premature; Hernia, inguinal; Herniorrhaphy; Infant, very low birth weight; Infant, newborn

Received: 10 May 2020

Revised: 22 June 2020

Accepted: 19 July 2020

Correspondence to: Ga Won Jeon, MD, PhD

Department of Pediatrics, Inje University Busan Paik Hospital, Inje University College of Medicine, 75 Bokji-ro, Busanjin-gu, Busan 47392, Korea

Tel: +82-51-890-6497

Fax: +82-51-890-5830

E-mail: iamgawon@hanmail.net

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INTRODUCTION

Failure of the patent processus vaginalis to close results in indirect inguinal hernia¹. The incidence of inguinal hernia ranges from 3% to 5% in term infants but is significantly higher in preterm infants, approximately 10% to 30%^{2,3}. Though inguinal herniorrhaphy is one of the most common operations performed by pediatric surgeons, the optimal timing of herniorrhaphy in preterm infants admitted in neonatal intensive care units (NICUs) is still controversial.

The incidence of bowel incarceration while waiting for an operation for an inguinal hernia is especially high in preterm infants⁴. Thus, herniorrhaphy shortly after diagnosis in the NICU is recommended to decrease the risks of incarceration and testicular ischemia^{5,6}. Some researchers highly recommend herniorrhaphy as soon as possible in preterm or very low birth weight (VLBW) infants when diagnosis is confirmed because of their high risk for incarceration⁷. In fact, pediatric surgeons usually perform herniorrhaphy before NICU discharge to avoid the need for readmission for herniorrhaphy as well as to decrease the risk of incarceration. Infants discharged from an NICU with known inguinal hernia frequently visit the emergency department before herniorrhaphy because of concerns about the hernia, which can cause pressure to their families⁸.

By contrast, researchers who advocate delayed operation are concerned about the increased risks of recurrence, postoperative apnea, and the need of mechanical ventilation associated with early operation before discharge from the NICU. Recent studies have found that herniorrhaphy before discharge from the NICU increased the risk of recurrence⁹ and delayed operation after discharge from the NICU did not increase the risks for preoperative incarceration and recurrence¹⁰. Early operation before NICU discharge did not prevent incarceration but prolonged the postoperative hospital stay and intubation as compared with operation after discharge from the NICU¹¹.

However, according to the survey of the American Academy of Pediatrics that detailed the timing of herniorrhaphy, up to 63% of surgeons perform herniorrhaphy before discharge from the NICU¹². Some pediatric surgeons prefer herniorrhaphy shortly after diagnosis in the NICU, whereas others prefer herniorrhaphy just before discharge from the NICU, and still others prefer herniorrhaphy as an outpatient after discharge from the NICU, waiting until the proper postmenstrual age (PMA) and body weight to reduce anesthetic risks and technical challenges.

Thus, the objective of this study was to determine the optimal timing of inguinal herniorrhaphy in preterm infants in the NICU to reduce the risks of preoperative incarceration in consideration of the possibilities of anesthetic and postoperative complications. We also evaluated the risk factors of postoperative apnea and contralateral metachronous inguinal hernia, based on which we suggest proper interventions to reduce the risks of postoperative apnea and metachronous hernia.

MATERIALS AND METHODS

Preterm infants with gestational age (GA) of <37 weeks who had been admitted to the NICU of Inje University Busan Paik Hospital (between January 2011 and December 2019) and had received inguinal herniorrhaphy by a single pediatric surgeon before the age of 6 months were enrolled. Early repair was defined as undergoing herniorrhaphy before discharge from the NICU, and late repair was defined as undergoing herniorrhaphy as an outpatient after discharge from the NICU according to the onset time of inguinal hernia.

Clinical data were collected retrospectively from the patients' medical records. Demographic factors and outcomes associated with the timing of repair were compared between the early- and late-repair groups. The demographic factors included GA, birth weight, sex, body weight at repair, postnatal age at repair (postnatal weeks), PMA at repair, and bronchopulmonary dysplasia (BPD). The outcomes included incarceration of inguinal hernia before repair, recurrence of inguinal hernia after repair, postoperative apnea, postoperative mechanical ventilation, and contralateral metachronous hernia. The risk factors of postoperative apnea were evaluated between the apnea and non-apnea groups. The risk factors of the development of contralateral metachronous hernia in unilateral hernia were evaluated.

BPD was defined as oxygen dependency or respiratory support at 36 weeks of PMA, with oxygen treatment for at least the first 28 days¹³. This disorder was categorized into three groups according to severity as follows: mild, moderate, or severe BPD. Postoperative apnea was defined as cessation of breathing for >15 seconds and typically accompanied by desaturation and bradycardia related to the operation or anesthesia, which was not detected immediately before operation. Postoperative mechanical ventilation was defined as the need for mechanical ventilation support for >24 hours due to the operation or anesthesia. General

anesthesia was used when regional anesthesia failed technically. Contralateral metachronous inguinal hernia was defined as a unilateral inguinal hernia at the first presentation with symptoms that develops into a contralateral hernia after surgical repair¹⁴.

We performed a *t*-test for the continuous variables with normal distributions and homogeneous variance, and used the Mann-Whitney *U*-test for variables without normal distributions or homogeneous variance, such as GA. The chi-square test or Fisher's exact test was used for the nominal variables. To adjust for the influences of GA and birth weight, multivariate logistic regression was used to determine the risk factors. All statistical analyses were performed using SPSS version 25.0 (IBM Co., Armonk, NY, USA). Data are presented as mean±standard deviation. *P* values of <0.05 were considered statistically significant.

RESULTS

Among the 148 preterm infants enrolled, 60 had herniorrhaphy before discharge from the NICU (early-repair group) and 88 had herniorrhaphy as an outpatient after discharge from the NICU (late-repair group). Male and female infants accounted for 65% and 35% of the patients, respectively. Right, left, and bilateral laterality was found in 48, 69, and 31 patients, respectively. In the male infants, right, left, and bilateral laterality was found in 41, 37, and 18 patients, respectively. In the female infants, right, left, and bilateral laterality was found in 7, 32, and 13 patients, respectively.

1. Comparison of the early- and late-repair groups

GA and birth weight were smaller in the early-repair group than in the late-repair group (29.4±2.9 weeks vs. 31.7±3.6 weeks, *P*<0.001; and 1,109±352 g vs. 1,613±585 g, *P*<0.001, respectively). Body weight at repair was smaller in the early-repair group than in the late-repair group (2,291±386 g vs. 3,925±1,159 g, *P*<0.001). Postnatal age and PMA at repair were younger in the early-repair group than in the late-repair group (9.2±3.5 weeks vs. 11.5±5.0 weeks, *P*=0.003; and 39.2±2.2 weeks vs. 43.6±4.4 weeks, *P*<0.001, respectively). BPD was more frequent in the early-repair group than in the late-repair group. However, no significant difference in BPD was found between the two groups after adjustments for GA and birth weight (19 [31.7%] vs. 11 [12.6%], *P*=0.005; adjusted *P*=0.202; odds ratio [OR], 2.193; 95% confidence interval [CI], 0.657 to 7.323). The incidence of moderate to severe BPD was not significantly different between the two groups (5 [8.5%] vs.

2 [2.3%], *P*=0.087). The frequency of herniorrhaphy performed under general anesthesia was not significantly different between the two groups (10 [16.7%] vs. 21 [23.9%], *P*=0.291).

The incidence of preoperative incarceration or recurrence was not significantly different between the two groups. Two patients in the late repair-group had incarcerated inguinal hernias. One patient visited the outpatient clinic as soon as the mother detected the inguinal mass, and inguinal herniorrhaphy was performed immediately after inguinal ultrasonography. The other patient visited the emergency department with severe inguinal swelling. Eight hours had passed after the inguinal mass was detected. Successful manual reduction under general anesthesia was performed, and inguinal herniorrhaphy was performed after 3 days. The bowel was intact and was not resected.

Postoperative apnea and mechanical ventilation were more frequent in the early-repair group than in the late-repair group (16 [26.7%] vs. 5 [5.7%], *P*<0.001; and 7 [11.7%] vs. 3 [3.4%], *P*=0.049, respectively). Postoperative apnea was more frequent in the early-repair group after adjustments for GA and birth weight (adjusted *P*=0.008; OR, 5.382; 95% CI, 1.551 to 18.676). However, no significant difference in postoperative mechanical ventilation was found between the two groups after adjustments for GA and birth weight (adjusted *P*=0.253; OR, 2.414; 95% CI, 0.532 to 10.959). Contralateral metachronous hernia was more frequent in the early repair group (12/41 [29.3%] vs. 4/76 [5.3%], *P*<0.001) (Table 1).

2. Risk factors of postoperative apnea

Among the 148 preterm infants enrolled, 21 presented with postoperative apnea. GA and birth weight were smaller in the apnea group (27.2±2.8 weeks vs. 31.4±3.2 weeks, *P*<0.001; and 1,000±470 g vs. 1,477±546 g, *P*<0.001, respectively). Body weight at repair was smaller in the apnea group (2,661±830 g vs. 3,362±1,254 g, *P*=0.002). Postnatal age at repair was rather older in the apnea group (13.1±4.8 weeks vs. 10.2±4.4 weeks, *P*=0.016), and PMA at repair was not significantly different between the apnea and non-apnea groups (40.9±5.6 weeks vs. 41.9±4.0 weeks, *P*=0.423). BPD and moderate to severe BPD were more frequent in the apnea group (16 [80.0%] vs. 14 [11.0%], *P*<0.001; and 6 [30.0%] vs. 1 [0.8%], *P*<0.001, respectively). They were still more frequent in the apnea group than in the non-apnea group after adjustments for GA and birth weight (BPD [adjusted *P*=0.001; OR, 16.187; 95% CI, 3.121 to 83.951]; moderate to severe BPD [adjusted *P*=0.004; OR, 40.264, 95% CI, 3.295 to 491.934]).

Table 1. Comparison of the Early- and Late-Repair Groups

Variable	Early-repair group (n=60)	Late-repair group (n=88)	P-value
Gestational age (wk)	29.4±2.9	31.7±3.6	<0.001
Birth weight (g)	1,109±352	1,613±585	<0.001
Male sex	40 (66.7)	56 (63.6)	0.705
Body weight at repair (g)	2,291±386	3,925±1,159	<0.001
Age at repair (wk)	9.2±3.5	11.5±5.0	0.003
PMA at repair (wk)	39.2±2.2	43.6±4.4	<0.001
BPD	19 (31.7)	11 (12.6)	0.005 (0.202*)
BPD (moderate to severe)	5 (8.5)	2 (2.3)	0.087
General anesthesia	10 (16.7)	21 (23.9)	0.291
Pre-operative incarceration	0	2 (2.3)	0.240
Recurrence	0	0	>0.999
Post-operative apnea	16 (26.7)	5 (5.7)	<0.001 (0.008 [†])
Post-operative ventilator	7 (11.7)	3 (3.4)	0.049 (0.253 [‡])
Laterality (right/left/bilateral)	18/23/19	30/46/12	0.068
Metachronous hernia	12/41 (29.3)	4/76 (5.3)	<0.001

Values are expressed as mean±standard deviation or number (%).

*Adjusted *P* for gestational age and birth weight=0.202 (OR, 2.193; 95% CI, 0.657 to 7.323); [†]Adjusted *P* for gestational age and birth weight=0.008 (OR, 5.382; 95% CI, 1.551 to 18.676); [‡]Adjusted *P* for gestational age and birth weight=0.253 (OR, 2.414; 95% CI, 0.532 to 10.959).

Abbreviations: PMA, postmenstrual age; BPD, bronchopulmonary dysplasia; OR, odds ratio; CI, confidence interval.

Table 2. Risk Factors of Postoperative Apnea

Variable	Apnea (n=21)	No-apnea (n=127)	P-value
Gestational age (wk)	27.2±2.8	31.4±3.2	<0.001
Birth weight (g)	1,000±470	1,477±546	<0.001
Body weight at repair (g)	2,661±830	3,362±1,254	0.002
Age at repair (wk)	13.1±4.8	10.2±4.4	0.016
PMA at repair (wk)	40.9±5.6	41.9±4.0	0.423
BPD	16 (80.0)	14 (11.0)	<0.001 (0.001*)
BPD (moderate to severe)	6 (30.0)	1 (0.8)	<0.001 (0.004 [†])
General anesthesia	12 (57.1)	19 (15.0)	<0.001 (<0.001 [‡])
Early repair	16 (76.2)	44 (34.6)	<0.001 (0.030 [§])

Values are expressed as mean±standard deviation or number (%).

*Adjusted *P* for gestational age and birth weight=0.001 (OR, 16.187; 95% CI, 3.121 to 83.951); [†]Adjusted *P* for gestational age and birth weight=0.004 (OR, 40.264; 95% CI, 3.295 to 491.934); [‡]Adjusted *P* for gestational age and birth weight <0.001 (OR, 8.116; 95% CI, 2.503 to 26.318); [§]Adjusted *P* for gestational age and birth weight=0.030 (OR, 4.032; 95% CI, 1.147 to 14.168).

Abbreviations: PMA, postmenstrual age; BPD, bronchopulmonary dysplasia; OR, odds ratio; CI, confidence interval.

Infants who underwent early repair were more frequent in the apnea group (16/21 [76.2%] vs. 44/127 [34.6%], *P*<0.001; adjusted *P* for GA and birth weight=0.030; OR, 4.032; 95% CI, 1.147 to 14.168). Herniorrhaphy performed under general anesthesia was more frequent in the apnea group (12/21 [57.1%] vs. 19/127 [15.0%], *P*<0.001; adjusted *P* for GA and birth weight <0.001; OR, 8.116; 95% CI, 2.503 to 26.318) (Table 2).

3. Factors related to the development of metachronous hernia in unilateral hernia

Sixteen preterm infants developed metachronous hernia (16/117 unilateral hernias, 13.7%). Most of the metachronous hernias occurred in the male infants (15/16, 93.8%). Body weight at repair was smaller in the metachronous hernia group than in the non-metachronous hernia group (2,458±635 g vs. 3,488±1,247 g, *P*=0.002). Postnatal age and PMA at repair were younger in the metachronous hernia group (8.6±3.3 weeks vs. 10.7±4.5 weeks,

Table 3. Factors Related to the Development of Metachronous Hernia in Unilateral Hernia

Variable	Metachronous hernia (n=16)	No metachronous hernia (n=101)	P-value
Gestational age (wk)	29.6±3.4	30.9±3.6	0.153
Birth weight (g)	1,211±497	1,468±582	0.074
Male sex	15 (93.8)	63 (62.4)	0.013
Body weight at repair (g)	2,458±635	3,488±1,247	0.002
Age at repair (wk)	8.6±3.3	10.7±4.5	0.032
PMA at repair (wk)	38.6±2.2	42.1±4.0	0.001
Early repair	12 (75.0)	29 (28.7)	<0.001

Values are expressed as mean±standard deviation or number (%).

Abbreviation: PMA, postmenstrual age.

$P=0.032$; and 38.6 ± 2.2 weeks vs. 42.1 ± 4.0 weeks, $P=0.001$, respectively). Of the 16 metachronous hernias, 11 (68.8%) occurred in VLBW infants, and 12 (75%) and four (25%) were primary right- and left-sided hernias, respectively. Infants who underwent early repair were more frequent in the metachronous than in the non-metachronous hernia group (12/16 [75.0%] vs. 29/101 [28.7%], $P<0.001$) (Table 3).

DISCUSSION

In the present study, early repair with herniorrhaphy before discharge from the NICU was performed at 9 weeks after birth and a PMA of 39 weeks, with a mean body weight of 2.3 kg. Late repair with herniorrhaphy as an outpatient after discharge from the NICU was performed at 12 weeks after birth and a PMA of 44 weeks, with a mean body weight of 3.9 kg.

Many pediatric surgeons perform herniorrhaphy before discharge from the NICU⁽¹²⁾ to avoid readmission of the patient for herniorrhaphy or the risk of preoperative incarceration while waiting for operation. Herniorrhaphy before discharge from the NICU was associated with recurrence, prolonged hospital stay, and postoperative mechanical ventilation, whereas herniorrhaphy after discharge from the NICU was associated with incarceration⁽¹⁵⁾. The frequency of early repair did not increase between 1999 and 2011 according to Sulkowski et al.⁽¹⁵⁾ but increased from 20% in 1998 to 45% in 2012 in another study⁽¹⁶⁾. Institutional practices for inguinal herniorrhaphy seem to vary.

Although the incidence of incarceration differs among the studies, the overall reported incidence of incarceration ranges from 12% to 17%⁽¹⁷⁾. The risk of bowel incarceration is especially

high in preterm infants than in term infants⁽¹⁸⁾. The incidence rates of incarceration were 25% and 13% at presentation and 11% and 3.4% at surgery in preterm and term infants, respectively, in the study of Hughes et al.⁽¹⁸⁾. The incidence of incarceration was >50% in the preterm infants, and emergency operations due to incarceration were more frequent in VLBW infants according to de Goede et al.⁽¹⁹⁾. Thus, they recommended herniorrhaphy during NICU admission, especially in VLBW infants, who have a high risk of incarceration while waiting for operation. By contrast, the incidence of incarceration was not different between preterm and term infants, and was low in both groups according to a nationwide survey in Taiwan (0.43% in preterm infants vs. 0.41% in term infants, $P=0.959$)⁽²⁰⁾. Relatively few incarcerations were reported in the present study. Only two cases of incarceration occurred before repair in the late-repair group, and no incarceration occurred in the early-repair group in the present study. Late repair with herniorrhaphy after discharge from the NICU did not increase the risk of incarceration in the present study. The result is similar to the finding that the waiting time for repair of a reducible hernia is not related to the increased risk of incarceration⁽²¹⁾. Olesen et al.⁽²²⁾ reported that herniorrhaphy does not need to be delayed unnecessarily because of the increased risk of incarceration. However, delayed repair can be justified in certain cases such as those with increased risk of anesthesia complication⁽²²⁾.

Early repair with herniorrhaphy before discharge from the NICU was associated with increased risk of recurrence⁽⁹⁾. The overall incidence of recurrence after herniorrhaphy is less than 1%⁽¹⁷⁾. However, the reported incidence of recurrence ranges from 1% to 9%. Half of the recurrent cases occurred within 1 year after herniorrhaphy⁽¹⁸⁾. No recurrent hernias were reported in the present study. The patients underwent routine follow-up as outpatients at the department of pediatric surgery a week after herniorrhaphy. No more routine follow-up visits were made if no complications occurred. This might have led to an underestimation of the recurrence rate.

Postoperative apnea was associated with low GA at birth and PMA at the time of operation⁽⁸⁾. In the present study, postoperative apnea was more common in the early-repair group than in the late-repair group. GA and birth weight were lower in the apnea group as expected; however, PMA at repair was not lower in the apnea group. PMA was around 41 weeks in both groups. Body weight at repair was smaller in the apnea group. We suggest that body weight at repair is also or even more important than PMA

in terms of the occurrence of postoperative apnea. According to the survey of the American Academy of Pediatrics, 10% of surgeons wait until infants reach a PMA of 50 weeks and 3 kg of body weight, which implies that surgeons also consider the importance of both body weight and PMA at repair¹². BPD and moderate to severe BPD were risk factors of postoperative apnea in the present study and were still significant factors for the development of postoperative apnea after adjustments for GA and birth weight. General anesthesia was also a risk factor of postoperative apnea in the present study and was more frequent in the apnea group. Regional anesthesia without preoperative sedatives reduced the risk of postoperative apnea, and regional anesthesia in inguinal herniorrhaphy was safer than general anesthesia according to a meta-analysis²³. General anesthesia was associated with prolonged anesthesia time and increased risk of postoperative intubation as compared with regional anesthesia²⁴. Thirteen percent of the patients in the early-repair group required postoperative intubation over 48 hours according to Lee et al.¹¹. Similarly, we found that 12% of the patients in the early-repair group required postoperative ventilation support in the present study (12% in the early-repair group vs. 3% in the late-repair group).

The overall incidence of contralateral metachronous hernia ranged from 6% to 10% of all cases of unilateral hernia, reaching up to 12.3% according to Lee et al.¹⁴. This correlates with the incidence rate of 13.7% in the present study. Primary left-sided hernia, younger age, and prematurity increase the risk of contralateral metachronous hernia²⁵. Metachronous hernia was more frequent in VLBW infants, with an incidence of 10% of all cases of unilateral hernia, which was more frequent in primary right-sided hernias (primary right-sided hernia: primary left-sided hernia ratio, 9:4) and males⁷. This correlates with our results. Metachronous hernia was more common in VLBW infants (11/16 metachronous hernias), primary right-sided hernia (primary right-sided hernia: primary left-sided hernia ratio, 12:4), and males (male:female ratio, 15:1) in the present study. We recommend that VLBW infants with primary right-sided hernia should be followed up carefully because of their risk of developing metachronous hernia. Demouron et al.²⁶ reported that in female preterm infants, metachronous hernia was more common in those with primary right-sided hernias, perhaps because right-sided inguinal hernias are more common than left-sided inguinal hernias. Metachronous hernia was more frequent in primary left-sided hernias in another study²⁷. By contrast, no significant difference in laterality was

found in another study¹⁰. Thus, the laterality of metachronous hernia is still controversial. Metachronous hernia was more frequent in the early-repair group in the present study. Moreover, smaller body weight at repair, younger age, and younger PMA at repair were associated with increased risk of metachronous hernia.

Inguinal hernia is twice as common on the right side than on the left side in term infants. However, bilateral inguinal hernia is more frequent in preterm infants than in term infants²⁸. The incidence rate of bilateral presentation was 21%, and that of right-sided presentation was relatively low (32%) in the present study, perhaps because all the enrolled infants were preterm. Male predominance was observed in the term infants, with a male-to-female ratio of 5:1 but was not significant in the preterm infants¹⁷. The male-to-female ratio was 1.8:1 in the present study.

This study has limitations. Assignment to the early- and late-repair groups was not randomized because of retrospective nature of the study. The subjects were allocated according to the onset time of inguinal hernia (before or after discharge from the NICU). Thus, confounding factors might exist despite the adjustments for GA and birth weight because of the retrospective nature of this study.

In summary, late repair was safe and did not increase the risk of incarceration or recurrence, and instead, decreased the risk of postoperative apnea and contralateral metachronous hernias in preterm infants with inguinal hernia. Postoperative apnea was associated with small body weight at repair, early repair, general anesthesia, younger GA, small body weight at birth, and BPD, as expected. We suggest that greater body weight at repair and regional anesthesia could reduce the risk of postoperative apnea. Male infants born with VLBW and a primary right-sided hernia are likely to develop a contralateral metachronous hernia. Thus, late repair can be considered to decrease the risk of contralateral metachronous hernia in such patients, who should be followed up carefully in case they develop a contralateral metachronous hernia. Further randomized prospective studies to compare the timing of herniorrhaphy are required.

ARTICLE INFORMATION

Ethical statement

This study was reviewed and approved by the Institutional Review Board of Inje University Busan Paik Hospital (identifica-

tion code: 20-0032) in accordance with the Declaration of Helsinki. The Institutional Review Board waived the need for informed consent for this retrospective chart review.

Conflicts of interest

No potential conflict of interest relevant to this article was reported.

Author contributions

Conception or design: J.S., G.W.J.

Acquisition, analysis, or interpretation of data: J.S., G.W.J.

Drafting the work or revising: J.S., G.W.J.

Final approval of the manuscript: J.S., G.W.J.

ORCID

Jaeho Shin <https://orcid.org/0000-0002-5393-542X>

Ga Won Jeon <https://orcid.org/0000-0002-8206-9727>

Acknowledgments

None

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