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Clinical paper

# Effect of stomach inflation during cardiopulmonary resuscitation on return of spontaneous circulation in out-of-hospital cardiac arrest patients: A retrospective observational study

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**Abstract**

**Background**: Gastric inflation caused by excessive ventilation is a common complication of cardiopulmonary resuscitation. Gastric inflation may further compromise ventilation via increases in intrathoracic pressure, leading to decreased venous return and cardiac output, which may impair out-of-hospital cardiac arrest (OHCA) outcomes. The purpose of this study was to measure the gastric volume of OHCA patients using computed tomography (CT) scan images and evaluate the effect of gastric inflation on return of spontaneous circulation (ROSC).

**Methods**: In this single-center, retrospective, observational study, CT scan was conducted after ROSC or immediately after death. Total gastric volume was measured. Primary outcome was ROSC. Achievement of ROSC was compared in the gastric distention group and the no gastric distention group; gastric distension was defined as total gastric volume in the ≥75th percentile. Additionally, factors associated with gastric distention were examined.

**Results**: A total of 446 cases were enrolled in the study; 120 cases (27%) achieved ROSC. The median gastric volume was 400 ml for all OHCA subjects; 1068 ml in gastric distention group vs. 287 ml in no gastric distention group. There was no difference in ROSC between the groups (27/112 [24.1%] vs. 93/334 [27.8%], $p = 0.440$). Gastric distention did not have a significant impact, even after adjustments (adjusted odds ratio 0.73, 95% confidence interval [0.42–1.29]). Increased gastric volume was associated with longer emergency medical service activity time.

**Conclusions**: We observed a median gastric volume of 400 ml in patients after OHCA resuscitation. In our setting, gastric distention did not prevent ROSC.

**Keywords**: Heart arrest, Cardiopulmonary resuscitation, Airway management, Ventilation, Insufflation, Regurgitation

## Introduction

Inflation of the stomach during cardiopulmonary resuscitation (CPR) is a common and significant complication.[1] Adequate ventilation plays an important role in maintaining tissue oxygenation during CPR. However, ventilation with excessive pressure/volume/rate, increased airway resistance, or impaired lung compliance may cause gastric air insufflation, potentially resulting in elevated intrathoracic pressure and lowered venous return and cardiac output.[2–4] Gastric distension can raise abdominal pressure with elevation of the diaphragm and may result in deteriorated ventilation by restricting lung expansion. In addition, gastric distension or restricted lung expansion may lead to a vicious cycle of decreased pulmonary compliance, which increases peak airway pressure and causes further stomach inflation. Gastric distention can lead to regurgitation of gastric contents and subsequent pulmonary aspiration, complicating patient care.[5,6]

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While advanced airway management techniques can help prevent air entry into the stomach, stomach inflation remains unavoidable, even with synchronized chest compressions and proper airway management.[1,5,7] Previous studies have shown that even moderate gastric distension from manual bag-valve-mask (BVM) ventilation negatively affects CPR and post-resuscitation care.[8,9]

Prior animal/cadaver studies demonstrate that excessive gastric distension and increased abdominal pressure have negative hemodynamic effects and result in decreased respiratory system compliance during CPR.[2,8,10] Berg et al. reported a pediatric cardiac arrest case with severe ventilatory compromise caused by gastric distention, which might have caused mortality of this patient.[9] However, the impact of gastric distension on cardiac arrest patient outcomes in the clinical setting has not been thoroughly investigated.

The purpose of this study was to examine the effect of gastric inflation, as measured by computed tomography (CT) scan images, on return of spontaneous circulation (ROSC) in out-of-hospital cardiac arrest (OHCA) patients. Additionally, we sought to identify factors associated with increased gastric volume upon arrival at the emergency department.

## Methods

### Study design and population

This was a retrospective, observational study conducted at Tsuyama Chuo Hospital, Japan on cases treated from May 1, 2014 to December 31, 2017. Tsuyama Chuo Hospital is the only tertiary hospital in the Mimasaka District with an area of 2743.3 km$^2$ and 300,000 residents from regions including both rural and sub-urban communities. Utstein style data from all OHCA patients who were treated by public emergency medical service (EMS) personnel and transported to our hospital were collected.[11] The Tsuyama Chuo Hospital Ethics Committee approved the study (ID: 350). The requirement for patient consent was waived because of the retrospective study design.

### EMS system and treatments

The EMS system in Japan has been described previously.[12] EMS personnel are activated by dialing an emergency number to reach the local fire department. Public EMS is available 24 hours every day; almost all OHCA transports are managed by public EMS. EMS activity is electronically recorded in the EMS database immediately after dispatch. An EMS team comprising more than three ambulance crew members is dispatched from the closest fire station to administer emergency care to OHCA patients. At least one emergency life-saving technician is required to be on the EMS team. Emergency life-saving technicians are authorized to place supraglottic airways (SGA) and intravenous access. Specially trained emergency life-saving technicians are allowed to perform endotracheal intubation (ETI) and administer adrenaline. OHCA patients are sent to the closest emergency hospital. EMS personnel are not permitted to stop resuscitation at the scene or during transport once resuscitation is initiated. Hospital advanced life support is generally conducted according to guidelines. At the emergency department, ETI is conducted for patients transported after BVM or SGA.

### Data collection and definition

All OHCA patients transported by local public EMS to Tsuyama Chuo Hospital were registered. Data from the public EMS registry was integrated with hospital medical record data. Physicians at the hospital were responsible for recording data on the form, including each patient's baseline characteristics, prehospital setting information, and treatments during transport. The following demographic information was collected: age, sex, witnessed arrest, bystander CPR, initial cardiac rhythm at the scene, presumed cardiac or non-cardiac cause, prehospital advanced life support (airway management, including BVM, SGA, ETI, adrenaline administration, defibrillation), prehospital time, ROSC, survival at 30 days, and Cerebral Performance Category score at 30 days. EMS activity time was defined as the time from EMS contact to hospital arrival. Prehospital techniques to secure airway were divided into three categories (BVM, SGA, or ETI); the most commonly used SGA device in the district is the laryngeal tube. In this study, ROSC was defined as approximately more than two minutes (one CPR cycle) of palpable pulse without CPR in either the prehospital or emergency room setting. Survived event was defined as prehospital ROSC sustained until arrival at our emergency department.

CT data was obtained from hospital medical records. A whole-body CT scan (GE Light Speed VCT 64, GE HealthCare Japan, Tokyo) was performed after patient stabilization following ROSC to search for the cause of cardiac arrest. This is standard care in our facility. Patients who had a gastric tube inserted before the CT scan were excluded from this study, since the stomach may have been decompressed with a gastric tube. If the patient did not gain ROSC or was pronounced dead in the emergency department, a CT scan was performed immediately after the death. In our district, a post-mortem CT scan is commonly requested by local police departments to investigate possible criminality.

We measured gastric volume using CT images (5 mm interval) and three-dimensional imaging software (FUJIN Anatomia, AZE, Tokyo). A region of interest (ROI) was obtained from each horizontal section. The gastric mucosa was manually traced. The total gastric volume was calculated by integrating the ROIs. Gastric volume was calculated as the volume from the sub-diaphragmatic point to the pyloric ring (Fig. 1). ROI was drawn by an emergency physician and confirmed by a certified radiologist. Additionally, pulmonary infiltrates were examined using CT images and recorded for their location and numbers of affected areas in each lobe.

### Inclusion and exclusion criteria

All adult OHCA patients ≥18 years of age transported to our hospital with total body CT scan examined after ROSC or death during the study period were included. Patients undergoing inter-facility transport, gastric tube insertion before CT, or extracorporeal CPR were excluded.

### Grouping and study endpoints

Subjects were divided into two groups according to gastric volume. The gastric distension group was defined as those with CT-measured gastric volumes in the ≥75th percentile. The remaining subjects were defined as the no gastric distension group. The primary outcome measured between the two gastric distension groups was ROSC. The association between gastric distention and clinical factors, including prehospital airway management (BVM, SGA, ETI), was examined. Additionally, the association between CT findings of pulmonary infiltrates and clinical factors were examined.

### Data analysis

Continuous variables are described using medians with interquartile ranges. Categorical variables are described using numbers and

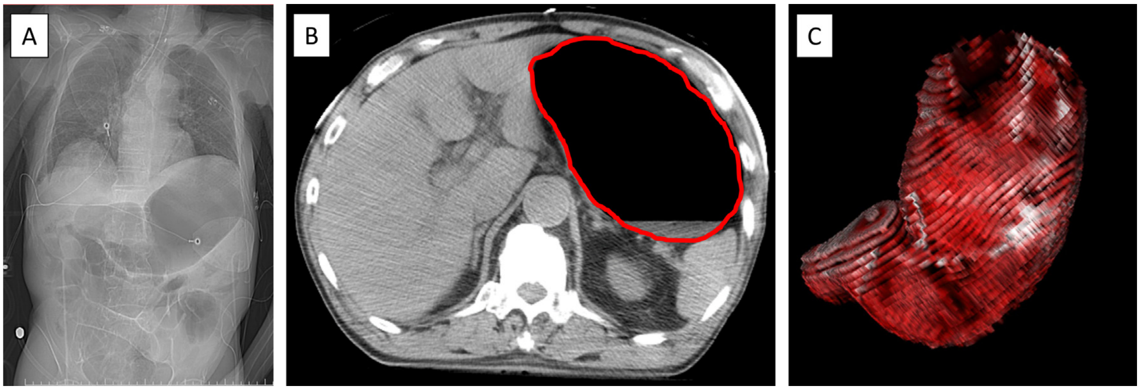

**Fig. 1 – We measured total gastric volume using three-dimensional imaging software (FUJIN Anatomia, AZE, Tokyo). A CT scout image of a typical case of gastric distention is shown in A. An ROI was obtained from each horizontal section. The gastric mucosa was manually traced (B). Total gastric volume was calculated by integrating the ROIs (C). The gastric volume was counted as the volume from the sub-diaphragmatic point to the pyloric ring. CT: computed tomography, ROI: region of interest.**

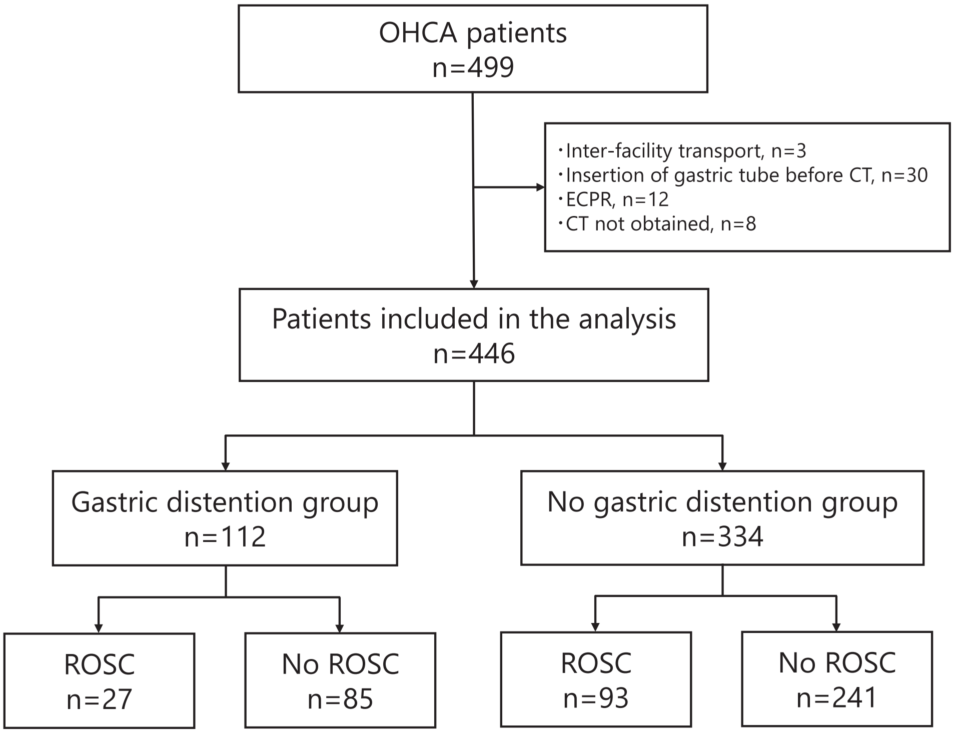

**Fig. 2 – Patient flow diagram. CT: computed tomography, ECPR: extracorporeal cardiopulmonary resuscitation, OHCA: out-of-hospital cardiac arrest, ROSC: return of spontaneous circulation.**

percentages. Chi-square test was used as an univariable analysis. A multivariable logistic regression analysis was used to adjust for factors associated with ROSC. We selected the following confounding variables: age, sex, witnessed collapse, initial shockable rhythm, estimated cardiac cause of arrest, bystander CPR, adrenaline administration, defibrillation, airway management (reference BVM), and EMS activity time. These variables were selected based on previous literature that suggested association with ROSC. Multivariable logistic regression was performed to examine the association between gastric distention and these clinical factors. We also performed multivariable logistic regression to examine the association of CT pulmonary infiltrates and a more limited set of clinical factors. Due to the small number of patients without infiltrates, adjustments for multivariable logistic regression were reduced: gastric distention, age, airway management, and EMS activity time. The results of logistic regression are described with odds ratio (OR) and a 95%

confidence interval (CI). A *p*-value <0.05 was considered significant. Statistical analysis was performed using STATA/SE 17 (StataCorp, Lakeway, TX, USA).

## Results

### *Patient characteristics*

A total of 499 OHCA patients were registered during the study period. After eligibility screening, 446 subjects were included (Fig. 2). Of the subjects eligible for analysis, 112 patients were in the gastric distention group and 334 subjects were in the no gastric distention group. ROSC was obtained in 120 (26.9%) subjects (27 [24.1%] in the gastric distention group and 93 [27.8%] in the no gastric distention group); 326 (73.1%) subjects died without ROSC (85 [75.9%] in the gastric distention group and 241 [72.2%] in the no gastric distention group). CT was performed following ROSC (90 subjects) or immediately after the death (30 subjects with ROSC but died at emergency department, 326 subjects without ROSC). Time from EMS contact to CT was 57 [48–67] min in all subjects, 58 [48–68] min in the gastric distention group, and 56 [48–67] min in the no gastric distention group).

Subject characteristics are shown in Table 1. The median age was 79 [IQR: 68–86], 54.7% were male, cardiac arrest was witnessed in 78.8% of subjects, bystander CPR was conducted in 44.1%, 3.9% had initial shockable rhythm at scene, and 45.2% had estimated cardiac cause for arrest. Prehospital treatments at the scene or during transport were as follows: defibrillation in 6.9%, adrenaline administered in 29.4%, and airway management methods were BVM: 34.2%, SGA: 55.6%, and ETI: 10.2%. Time from EMS activation to hospital arrival was 24 [20–32] min. ROSC was seen in 26.9%, survived event in 5.3%, 30-day survival in 3.4%, and favorable neurological outcome in 1.6%.

### *Gastric volume measurement and ROSC*

The median gastric volume was 400 [192–793] ml for all subjects. The gastric volumes corresponding to each quartile were: 0–25 percentile [12.9–191] ml, 25–50 percentile [191–400] ml, 50–75 percentile [400–793] ml, and 75–100 percentile [793–2673] ml, respectively. There were no differences in achieving ROSC between each quartile: 0–25 percentile 25/111 (22.5%, 95% CI [15.1–31.4]), 25–50 percentile 30/112 (26.8%, 95% CI [18.9–36.0]), 50–75 percentile 38/111 (34.2%, 95% CI [25.5–43.8]), 75–100 percentile 27/112 (24.1%, 95% CI [16.5–33.1]). The median gastric volume of

**Table 1 – Patient characteristics.**

| | All (*n* = 446) | Gastric Distension (*n* = 112) | No Gastric Distension (*n* = 334) |
|---|---|---|---|
| Age, median (IQR), y | 79 (68–86) | 77 (65–85) | 80 (69–87) |
| Sex | | | |
| Male, *n* (%) | 244 (54.7) | 71 (63.4) | 173 (51.8) |
| Female, *n* (%) | 202 (45.3) | 41 (36.6) | 161 (48.2) |
| Witnessed arrest, *n* (%) | 150 (33.6) | 37 (33.0) | 113 (33.8) |
| Bystander CPR, *n* (%) | 197 (44.1) | 57 (50.8) | 140 (41.9) |
| Initial rhythm at the scene[a] | | | |
| Shockable rhythm, *n* (%) | 17 (3.9) | 8 (7.2) | 9 (2.7) |
| Non-shockable rhythm, *n* (%) | 422 (96.1) | 103 (92.8) | 328 (97.3) |
| Estimated cause of cardiac arrest | | | |
| Cardiac cause, *n* (%) | 202 (45.2) | 45 (40.1) | 157 (47.0) |
| Non-cardiac cause, *n* (%) | 244 (54.8) | 67 (59.9) | 177 (53.0) |
| Prehospital advanced life support care | | | |
| Adrenaline administration, *n* (%)[b] | 131 (29.4) | 91 (27.3) | 40 (35.7) |
| Airway management, *n* (%)[c] | | | |
| Endotracheal intubation, *n* (%) | 41 (10.2) | 13 (12.9) | 28 (9.3) |
| Supraglottic airway, *n* (%) | 223 (55.6) | 57 (56.4) | 166 (55.3) |
| Bag valve mask, *n* (%) | 137 (34.2) | 31 (30.7) | 106 (35.3) |
| Defibrillation, *n* (%) | 31 (6.9) | 13 (11.6) | 18 (5.3) |
| Time from EMS call to hospital arrival, median (IQR), min | 38 (31–47) | 39 (32–47) | 38 (30–46) |
| EMS activity time (EMS contact to hospital arrival), median (IQR), min | 24 (20–32) | 25 (21–34) | 24 (19–31) |
| Time from EMS contact to CT, median (IQR), min | 57 (48–67) | 58 (48–68) | 56 (48–67) |
| Gastric volume, median (IQR), ml | 399 (191–793) | 1068 (901–1240) | 287 (140–476) |
| CT pulmonary infiltrate detected, *n* (%) | 389 (87.2) | 100 (89.3) | 289 (86.5) |
| Number of pulmonary lobes with infiltrate, median (IQR), | 5 (2–5) | 4 (2–5) | 5 (2–5) |
| ROSC, *n* (%) | 120 (26.9) | 27 (24.1) | 93 (27.8) |
| Survived event, *n* (%) | 24 (5.3) | 6 (5.3) | 18 (5.3) |
| Favorable neurological outcomes at 30-days, *n* (%)[d] | 7 (1.6) | 3 (2.7) | 4 (1.2) |
| 30-day survival, *n* (%)[e] | 15 (3.4) | 3 (2.7) | 12 (3.7) |

CPR: cardiopulmonary resuscitation, CT: computed tomography, EMS: emergency medical service, IQR: interquartile range, ROSC: return of spontaneous circulation.

[a] 1 and 6 patients were missing in the gastric distension and the no gastric distension group, respectively.

[b] 1 patient was missing in the no gastric distension group.

[c] 11 and 34 patients were missing in the gastric distension and the no gastric distension group, respectively.

[d] 4 and 13 patients were missing in the gastric distension and the no gastric distension group, respectively.

[e] 4 and 10 patients were missing in the gastric distension and the no gastric distension group, respectively.

the gastric distension group was 1,068 [901–1240] ml and median gastric volume of the no gastric distension group was 287 [140–476] ml. There was no difference in ROSC between the gastric distention group and the no gastric distention group in univariable analysis (27/112 [24.1%] vs. 93/334 [27.8%], $p = 0.440$). Multivariable logistic regression analysis (Table 2) conducted to examine the association between ROSC and clinical factors demonstrated that gastric distention was not associated with ROSC (OR 0.73, 95% CI [0.42–1.29]). There was no difference in survived event between the gastric distention group and the no gastric distention group in univariable analysis (6/112 [5.3%] vs. 18/334 [5.3%], $p = 0.990$).

### *Clinical factors for gastric distention*

Clinical factors that may cause gastric distention are shown in Table 3. Airway management maneuvers on arrival did not affect gastric distention, BVM: reference, SGA: adjusted OR 0.94 (95% CI [0.54–1.61]), ETI: adjusted OR 1.58 (95% CI [0.53–2.72]). Longer EMS activity duration was positively associated with gastric distention: adjusted OR 1.03 (95% CI [1.00–1.06]).

### *Clinical factors for pulmonary infiltration*

Pulmonary infiltration detected by CT was noted in 87.2% of all the patients. The median number of pulmonary lobes with infiltrates was 5.[2–5] The association between pulmonary infiltration and clinical factors is shown in Table 4. Gastric distention did not affect pulmonary infiltration: adjusted OR 1.40 (95% CI [0.66–2.96]). Airway management maneuver on arrival did not affect pulmonary infiltration, BVM: reference, SGA: adjusted OR 1.18 (95% CI [0.61–2.27]), ETI: adjusted OR 0.99 (95% CI [0.33–2.95]). Older age was associated with increased pulmonary infiltration: adjusted OR 1.02 (95% CI [1.00–1.04]).

**Table 2 – Association between ROSC and clinical factors, including gastric distention, in multivariable logistic regression analysis.**

| | Adjusted OR (95% CI) |
|---|---|
| Gastric distension | 0.74 (0.42–1.31) |
| Age | 1.01 (0.99–1.02) |
| Sex (male) | 0.94 (0.57–1.52) |
| Witnessed collapse | 1.87 (1.14–3.07) |
| Initial shockable rhythm | 2.13 (0.49–9.26) |
| Estimated cardiac cause of arrest | 0.69 (0.42–1.13) |
| Bystander CPR | 1.05 (0.65–1.70) |
| Defibrillation | 0.81 (0.46–1.44) |
| Airway management | |
| Bag valve mask | Reference |
| Supraglottic airway | 0.98 (0.57–1.66) |
| Endotracheal intubation | 1.77 (0.81–3.87) |
| Adrenaline administration | 1.08 (0.83–1.42) |
| EMS activity time (EMS contact to hospital arrival) | 0.99 (0.96–1.02) |

Gastric distention, age, sex, witnessed collapse, initial shockable rhythm, estimated cardiac cause of arrest, bystander CPR, defibrillation, airway management, adrenaline administration, and EMS activity time were used to adjust for the outcomes in the multivariate logistic regression.

CI: confidence interval, CPR: cardiopulmonary resuscitation, EMS: emergency medical service, OR: odds ratio, ROSC: return of spontaneous circulation.

**Table 3 – Association between gastric distension and clinical factors in multivariable logistic regression analysis.**

| | Adjusted OR (95% CI) |
|---|---|
| Airway management | |
| Bag valve mask | Reference |
| Supraglottic airway | 0.94 (0.54–1.61) |
| Endotracheal intubation | 1.58 (0.53–2.72) |
| Age | 0.99 (0.98–1.01) |
| Sex (male) | 1.55 (0.94–2.56) |
| Witnessed collapse | 0.85 (0.50–1.45) |
| Initial shockable rhythm | 1.96 (0.53–7.19) |
| Estimated cardiac cause of arrest | 0.74 (0.45–1.21) |
| Bystander CPR | 1.46 (0.89–2.38) |
| Defibrillation | 1.21 (0.81–1.79) |
| Adrenaline administration | 1.20 (0.93–1.55) |
| EMS activity time (EMS contact to hospital arrival) | 1.03 (1.00–1.06) |

Airway management, age, sex, witnessed collapse, initial shockable rhythm, estimated cardiac cause of arrest, bystander CPR, defibrillation, adrenaline administration, and EMS activity time were used to adjust for the outcomes in the multivariate logistic regression.

CI: confidence interval, CPR: cardiopulmonary resuscitation, EMS: emergency medical service, OR: odds ratio.

**Table 4 – Association between pulmonary infiltrates and clinical factors, including gastric distention, in multivariable logistic regression analysis.**

| Variable | Adjusted OR (95% CI) |
|---|---|
| Gastric distension | 1.40 (0.66–2.96) |
| Age | 1.02 (1.00–1.04) |
| Airway management | |
| Bag valve mask | Reference |
| Supraglottic airway | 1.18 (0.61–2.27) |
| Endotracheal intubation | 0.99 (0.33–2.95) |
| EMS activity time | 1.01 (0.97–1.04) |

Variables: gastric distention, age, airway management, and EMS activity time were used to adjust for the outcomes in the multivariable logistic regression.

CI: confidence interval, EMS: emergency medical service, OR: odds ratio, CI: confidence interval.

## Discussion

This is the first study investigating whether excessive gastric inflation, as measured on CT, is associated with ROSC in humans. Our data demonstrated that median total gastric volume was 400 ml for all OHCA subjects; 1068 ml in the gastric distention group (defined as gastric volume in the 75th percentile or higher) vs. 287 ml in the no gastric distention group. There was no difference in achieving ROSC between subjects with gastric distention compared to subjects with no gastric distention, suggesting that the amount of air insufflated into the stomach during CPR in clinical practice is not associated with ROSC.

Several large animal studies using swine models of cardiac arrest have investigated the effects of gastric inflation. Increased level of stomach inflation had adverse effects on hemodynamic status with higher mean pulmonary artery pressure and decreased static pulmonary compliance, associated with increased mortality and decreased stroke volume index.[8,10] Paal et al. demonstrated that increasing levels of stomach inflation had adverse effects on hemodynamic and pulmonary function during CPR.[10] Impaired respiratory system mechanics and reduced left cardiac function were observed, even at an intra-abdominal pressure of 12 and 15 mmHg in a sheep laparoscopic procedure model.[13] Wenzel et al. reported that respiratory system compliance decreased significantly after CPR and there was subsequent induction of stomach inflation in a pig model with an unprotected airway.[3] It is possible that our study did not find an association between ROSC and gastric distention due to the relatively small amount of inflated air (median 400 ml) in the clinical setting compared with animal models.

Aufderheide et al. reported that professional rescuers use ventilation techniques that would result in gastric inflation.[14] Gastric inflation was observed in 12% of subjects resuscitated for cardiac arrest where BVM was used to provide ventilatory support.[15] Previous studies describe that the incidence of gastric inflation increased with inspiratory pressure during unsecured ventilation compared to advanced airway management.[16–18] Importantly, our data demonstrate that gastric volume measured using CT at the time of emergency room visit did not differ between airway management procedures, suggesting that advanced airway devices may not prevent gastric distension. Manual ventilation using BVM prior to securing the airway may have caused gastric insufflation. Unfortunately, we do not have data to determine at which time point after OHCA gastric inflation occurred, since stomach inflation was not monitored during the CPR process. Gastric distension may be caused by first-line bystander CPR, including mouth-to-mouth ventilation or BVM ventilation by the EMS team in the early stage of CPR, since high inspiratory pressures may be necessary to overcome the low pulmonary compliance with initial ventilation.

Gastric inflation may be affected during resuscitation, depending on airway resistance, lung volume/compliance, diaphragmatic mechanics, and abdominal pressure. Pulmonary compliance decreases during CPR[19] and is further affected by alveolar collapse.[20,21] The lower esophageal sphincter may prevent or limit stomach inflation during positive pressure ventilation. However, during cardiac arrest, lower esophageal sphincter pressure decreases from approximately 20 $cmH_2O$ to approximately 5 $cmH_2O$,[22–23] thus decreasing its effectiveness at preventing gastric inflation. A high level of inspiratory pressure may result in increased ventilation pressure that opens the lower esophageal sphincter.[19] The combination of these physical and anatomical variables and ventilatory techniques during unsecured ventilation determines gas distribution between the lungs and stomach. A study in human cadavers demonstrated that continuous oxygen insufflation induced less gastric inflation than intermittent insufflation during CPR.[5]

Gastric inflation in an unconscious patient increases the potential for regurgitation and aspiration of gastric contents, followed by early-onset pneumonia, which is a common infectious complication in resuscitated OHCA patients.[6] Gastric volume may change during transport to the hospital and may induce regurgitation; it is possible that this process influenced the lack of association between gastric distention and pulmonary infiltration. Prior literature has demonstrated that in almost half of CPR patients, ventilation with an unprotected airway resulted in stomach inflation-mediated regurgitation and subsequent pulmonary aspiration.[24] In our study, pulmonary CT soon after patient arrival revealed any infiltrate in 87.2% of the patients. However, these abnormalities are likely to include conditions other than aspiration.

### *Limitations*

Our study has several limitations. First, this is a retrospective, observational study with a small number of subjects who had a low rate of survival or functional neurological outcome. Our primary outcome measure was ROSC; survived event, survival, or functional neurological outcome were not considered due to the small number of subjects. Second, we did not measure parameters related to respiration or circulation, nor did we evaluate relevant factors such as intra-abdominal or intra-thoracic pressure. Therefore, the impact of gastric distention on respiration or circulation during CPR remains unknown. Third, the impact of regurgitation during transport or treatment was not considered, but stomach volume likely changes over time during CPR. Fourth, CPR guidelines were updated in 2020. Moreover, use of the laryngeal tube has been replaced by new types of SGA devices in some emergency medical systems. Fifth, we were unable to measure intestinal volume, which might have caused more abdominal distension than we measured. We measured total gastric volume. However, the air that passed through the pylorus into the intestines may additionally compromise venous return to the heart. Sixth, patients with gastric tube insertion before CT were excluded from the study; this may have caused underestimation of gastric volume because these patients may have had distended abdomens with large amounts of gastric volume; however, the number of excluded patients was not large (30 patients). Finally, patients without ROSC may have had longer resuscitation times, resulting in increased gastric volume. This could overestimate the effect of gastric volume on ROSC; however, we did not find evidence that gastric distension was associated with ROSC.

## Conclusions

After OHCA resuscitation, gastric inflation resulted in a median gastric volume of 400 ml in our clinical setting. Although our study was not sufficiently powered to determine survival or favorable neurological outcomes, in our setting, gastric distention did not prevent ROSC.

## Ethics approval and consent to participate

This study conforms to the principles outlined in the Declaration of Helsinki and was approved by ethics committee of the Tsuyama Chuo Hospital (approval number: 350). Patient consent was waived for all participants enrolled in this study because of the retrospective study design.

## Consent for publication

Consent for publication was waived.

## Availability of data and materials

The datasets from this study are available from the corresponding author upon reasonable request.

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This study was granted by Nippon Kyukyu Iryo Zaidan.

## CRediT authorship contribution statement

**Hiroaki Hanafusa:** Writing – review & editing, Methodology, Conceptualization. **Takashi Hongo:** Writing – review & editing, Methodology, Formal analysis, Data curation. **Tetsuya Yumoto:** Writing – review & editing, Methodology, Data curation. **Takashi Yorifuji:** Writing – review & editing, Methodology, Formal analysis, Data curation. **Alexandra Weissman:** Writing – review & editing, Methodology, Conceptualization. **Jon C. Rittenberger:** Writing – review & editing, Methodology, Conceptualization. **Francis X. Guyette:** Writing – review & editing, Methodology, Conceptualization. **Mamoru Fujishima:** Writing – review & editing, Methodology, Investigation, Data curation, Conceptualization. **Hiroki Maeyama:** Writing – review & editing, Methodology, Conceptualization. **Astunori Nakao:** Writing – original draft, Supervision, Project administration, Methodology. **Hiromichi Naito:** Writing – original draft, Methodology, Investigation, Conceptualization, Formal analysis, Data curation, Project administration, Funding acquisition.

## Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: 'The study received grand from Nippon Kyukyu Iryo Zaidan. The authors declared no other potential conflicts of interest with respect to the research, authorship, and/or publication for this article'.

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