Measuring Changes in Stroke Volume Variation After a "Tidal Volume Challenge" To Predict Desufflation Induced Hypotension During Pediatric Laparoscopic Surgery, A Prospective Cohort Study

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Background: Currently, laparoscopic surgeries are used for many abdominal and pelvic procedures in pediatric patients. Prediction of post desufflation hypotension is important to identify at-risk patients and to take suitable measures to prevent such complication. **Aim:** to evaluate the ability of SVV measured by EC to predict desufflation hypotension in pediatric population. **Patients and Methods:** This prospective cohort clinical study was conducted at Pediatric Cairo University Hospital (Abu Elrish Hospital). All consecutive pediatric patients under the age of 5 yrs, who underwent general anesthesia for laparoscopic surgery were enrolled in this prospective study. **Results:** Analysis of the receiver operating characteristic curves revealed that each of SVV8, delta SVV, and heart rate could predict post-desufflation hypotension with the SVV8 having the highest predictive properties (AUC [95% CI]: 0.799[0.6770.921] sensitivity 72%, specificity 80%, cutoff value: >15%), followed by delta SVV (AUC [95% CI]: 0.766[0.635-0.896] sensitivity 72%, specificity 77%, cutoff value: >3%), and heart rate (AUC [95% CI]: 0.679[0.543-0.816] sensitivity 89%, specificity 57%, cutoff value: >121); while, each of MAP and cardiac index (at T2) did not predict hypotension. **Conclusion:** Stroke Volume Variation and tidal volume challenge test can be useful tools to predict post-desufflation hypotension during pediatric laparoscopic surgery:

Keywords: Stroke Volume Variation, Tidal Volume Challenge, Desufflation, Laparoscopic Surgery

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Introduction

Currently, laparoscopic surgeries are used for many abdominal and pelvic procedures in pediatric patients. Laparoscopic surgeries have many advantages in comparison to open procedures such as less postoperative pain due to small incisions, earlier mobilization, shorter hospital stays and lower incidence of infections. **(1, 2)**

However, laparoscopic surgeries are associated with haemodynamics sequalae during gas insufflation as well as after gas desufflation. The sudden reduction in intra-abdominal pressure (IAP) may result in hypotension due to increased capacitance of the gastrointestinal venous reservoir and subsequently reduction of venous return. **(3)**

The incidence of desufflation induced hypotension is about 27 %. Prediction of post desufflation hypotension is important to identify at-risk patients and to take suitable measures to prevent such complication. Previous reports showed that hypovolaemia increases the risk of post desufflation hypotension. **(4, 5);** hence, dynamic indices for volume status can be used for prediction of post-desufflation hypotension. **(6)**

Additionally, respiratory variation in the pulse oximetry plethysmographic waveform (POP) can be used to predict desufflation-induced hypotension during paediatric laparoscopic surgery. 6 But, many factors may affect accuracy of pulse oximetry devices such as hypothermia, arterial vasoconstriction, low cardiac output or elevated cutaneous vascular resistance. **(7)**

Stroke volume variation (SVV) is one of dynamic indices that can be used for prediction of fluid responsiveness in mechanically ventilated patients and prediction of post induction hypotension. **(8,9)** However, its ability to predict post desuflation hypotension in pediatric population is not yet evaluated.

Furthermore, SVV can be assessed noninvasively via electric cardiometry (EC) and its measurement is not affected by systemic vascular resistance (SVR) or operator experience. **(10)**

Therefore, in this study we aimed to evaluate the ability of SVV measured by EC to predict desufflation hypotension in pediatric population.

Methods

This prospective cohort clinical study was conducted at Pediatric Cairo University Hospital (Abu Elrish Hospital) after the Institutional Research Ethics Committee approval (MD-14-2020). Informed consents were obtained from parents of all patients in the study.

All consecutive pediatric patients under the age of 5 yrs. who underwent general anesthesia for laparoscopic surgery were enrolled in this prospective study. Children above 5 years, ASA class > I, Patients with cardiac arrhythmia, LV dysfunction (preoperative LV ejection fraction <30%), a congenital syndrome, congenital heart disease or respiratory disease (i.e., *pneumonia, atelectasis, bronchial asthma) were excluded from the study. We also excluded surgeries with* duration over 120 min and those converted to open surgery.

Patients were premedicated with intramuscular midazolam 0.3 mg/kg and atropine 0.02 mg/Kg. Upon arrival to the operation room (OR) ECG monitor, SpO_2 probe, and non-invasive blood pressure were attached to the patient. Anesthesia was induced with 6–8 vol% sevoflurane with 100% O_2 mask ventilation. After securing an intravenous cannula, fentanyl at a dose of 2 µg/kg was given, followed by atracurium at a dose of 0.5 mg/kg to facilitate tracheal intubation. Mechanical ventilation was instituted in a volume-controlled mode (Datex-Ohmeda Avance CS^2 Anesthesia Machine; GE Healthcare, Helsinki, Finland) with a tidal volume of 6 ml/kg, inspiration: expiration ratio of 1:2, and a respiratory frequency of 12-20/ min to maintain normocapnia during surgery (end-tidal carbon dioxide tension between 32 and 37 mmHg). PEEP was not applied. A heat blanket and forced-air warming system (Bair Hugger Warming System; Augustine Medical, Eden Prairie, MN, USA) were used to maintain a core temperature >36 °C. Anesthesia was maintained with 1–1.5 vol% isoflurane and an oxygen/air mixture. During the laparoscopic procedure, IAP was maintained at 12 mm Hg; all patients were maintained in the supine position. The child's data (age, weight, and height) were registered on EC before attachment. Four skin EC sensors were applied: on the forehead, on the left base of the neck, on the lower left thorax at the level of xiphoid and a fourth one on the lower left thorax approximately 5 cm below the 3rd electrode at the level of anterior axillary line and at the same side of the chest. To exclude the impact of fluid on the SVV, an infusion of Ringer's acetate solution was administered intraoperatively at a constant rate (6 ml/kg/h) to cover the fluid deficit and basal fluid requirements.

Data were collected at the following time points: T_0=baseline (stable conditions after induction of anesthesia), the hemodynamic response to 6 ml/kg of V_T ventilation (SVV_6), and were recorded as T_1 (T1=5 min after insufflation). Five minutes before gas desufflation, the V_T challenge was done as following: V_T was increased from 6 to 8 ml/kg for 3 min without changing the RR. During the last minute of high V_T ventilation, measurements of the above-mentioned hemodynamic and respiratory variables, including SVV_8, were again recorded (T_2). *T_2*=1 min before desufflation, and *T_3*=immediately after desufflation up to 1 min.

The changes in SVV values induced by V_T challenge ($\Delta SVV_{6–8}$) were calculated as follows: $\Delta SVV_{6–8}=SVV_8−SVV_6$. And the percentage change SVV values induced by V_T challenge (%$\Delta SVV_{6–8}$) were also calculated as: 100*($\Delta SVV_{6–8}$ / SVV_6)

Significant post-desufflation hypotension was defined as >20% decrease in mean arterial pressure (MAP) of T0 at the time of desufflation. Subjects with significant hypotension were allocated into the H (significant Hypotension) group and subjects with stable blood pressure were allocated into the S (hemodynamically Stable) group.If post-desufflation hypotension occurred, a bolus of Ringer's solution at a dose of 10 mL/Kg was given and repeated twice if needed. If the patient is non-responder, ephedrine was used in a dose of 0.1-0.2 mg/kg.

Primary outcome was sensitivity and specificity of *$\Delta SVV_{6–8}$* measured by EC to predict post-desufflation hypotension. Others outcomes included Incidence of post-desufflation hypotension, Correlation between SVV_6 and post-desufflation hypotension *and also Correlation between SVV_8* and post-desufflation hypotension.

Statistical Analysis

Sample size was performed using the Medcalc program (version 18) on the level of sensitivity of ΔSVV measured by EC to predict post-desufflation hypotension using the ROC curve because it was the primary outcome variable in this study. We used a more conservative assumption to detect an AUROC of 0.75. For a power of 0.8 and an alpha error of 0.05, and assuming a ratio of 1:3 between positive cases (hypotension with deflation) and negative cases (no hypotension with deflation), a minimum sample size of 56 patients was calculated with at least 14 positive cases and 42 negative cases after excluding dropouts. The Sample size is increased to 62 for possible dropouts.

Statistical package for social science (SPSS) software, version 15 for Microsoft Windows (SPSS Inc., Chicago, iL, USA) were used for data analysis. Categorical data were expressed as frequency (%) and were analyzed using chi-squared test or fisher's exact test as deemed appropriate. Continuous data were tested for normality using Shapiro-Wilk test and were presented as either mean (standard deviation), or median (quartiles) as appropriate. Continuous data were analyzed using one-way analysis of variance (ANOVA) with post-hoc Tukey modification (for normally distributed data) and using Kruskal-Wallis test on ranks (for skewed data). For repeated measures, a two-way repeated measures ANOVA were used to evaluate inspiratory pressure (between-groups factor) and time (repeated measures). Post-hoc pairwise comparison was performed using Bonferroni test. A p value of ≤ 0.05 was considered statistically significant.

Results

Sixty-two patients were available for final analysis. The two study groups, namely hypotension and non-hypotension groups, were comparable with regard to age, weight, type of surgery, and tidal volume. The frequency (%) of males were lower in the hypotension group compared to the no-hypotension group (7[39%] vs 31[70%], *P*=0.04). With exception of the baseline MAP, all other hemodynamic variables (heart rate, CI, and SVV) were comparable in the two groups. The hypotension group showed higher baseline MAP compared to the no-hypotension group (82±14 mmHg vs 70±12 mmHg, *P*=0.002) (Table 1).

At T1 (post-insufflation at VT 6 mL/kg) and T2 (at VT 8 mL/kg), the hypotension group showed comparable hemodynamic heart rate, SBP, MAP, and CI compared to the no-hypotension group (table 2) (Fig 2). However, the SVV was significantly higher in the hypotension group compared to the no-hypotension group at all T1, T2, and T3 (T1: 13.3± 5% vs 10.5± 4%, *P*=0.028), (T2: 16± 3.12% vs 11.9± 4.1%, *P*<0.001), (T3:

17.3± 5.2% vs11±3.7%, *P*<0.001) (Table 2) (Fig 2,3).

Within the hypotension group, the T3 measuring point showed increasing the heart rate compared the baseline reading; while each of the SBP, MAP, and CI decreased at T3 compared to the baseline reading (Fig 6). The SVV increased within the hypotension group at all points (T1, T2, and T3) compared to the baseline reading (Table 2) (Fig 3).

Within the no-hypotension group, the heart rate decreased and SBP increased at each of T2 and T3 compared to the baseline reading; while the MAP increased at the three time points (T1, T2, and T3) compared to the baseline reading (Table 2) (Fig 2).

Analysis of the receiver operating characteristic curves revealed that each of SVV8, delta SVV, and heart rate could predict post-desufflation hypotension with the SVV8 having the highest predictive properties (AUC [95% CI]: 0.799[0.6770.921] sensitivity 72%, specificity 80%, cutoff value: >15%), followed by delta SVV (AUC [95% CI]: 0.766[0.635-0.896] sensitivity 72%, specificity 77%, cutoff value: >3%), and heart rate (AUC [95% CI]: 0.679[0.543-0.816] sensitivity 89%, specificity 57%, cutoff value: >121); while, each of MAP and cardiac index (at T2) did not predict hypotension (Table 3)(Figure 4).

Table 1: demographic data and patient characteristics. Data are presented as mean± standard deviation). Median (quartiles), and frequency (%).

	Hypotension (n=18)	No hypotension (n=44)	P value
Age (months)	36(5.25-39)	24(12-60)	0.31
Weight (kg)	15(6.5-20)	14(10-25)	0.33
Male gender (n[%])	7(39%) *	31(70%)	0.04
Type of surgery	CDH (11%) Inguinal Hernia (17%) Abdominal Cysts (17%) Duodenal web (17%) Vaginoplasty (17%) CHPS (11%) Undescended testis (5%) Appendicitis (5%)	CDH (7%) Inguinal Hernia (25%) Abdominal cysts (13%) Cholecystectomy (7%) Vaginoplasty (7%) CHPS (7%) Undescended Testis (30%) Rectal Prolapse (4%)	0.5
Tidal volume (mL)	89±43	107±51	0.2
End-tidal CO2 (mmHg)	32.9 2.9	33.3 2.8	0.68
Heart rate (bpm)	134±18	125±24	0.13
MAP (mmHg)	82±14 *	70±12	0.002
CI (L/min)	4.22±1.26	4.44±0.966	0.45
SVV (%)	11±3.4	11.2±3.4	0.84

CDH; Congenital Diaphragmatic Hernia, CI: cardiac index, CO2; Carbon Dioxide, MAP: mean arterial pressure, SVV: stroke volume variations. *denotes statistical significance.

Table 2: Hemodynamic variables. Data are presented as means ±(standard deviations).

	baseline	T1	T2	T3
Heart rate (bpm) Hypotension (n=18) No hypotension (n=44)	134± 18 125± 24	134± 17 125± 23	130± 14 119± 22†	132± 19* 118± 25†
SBP (mmHg) Hypotension (n=18) No hypotension (n=44)	108± 18 100± 16	104± 16 106± 19‡	103± 16 105± 17‡	90± 12*† 103± 21
MAP (mmHg) Hypotension (n=18) No hypotension (n=44)	82± 14* 70± 13	78± 14 76± 17‡	73± 15† 74± 13‡	61± 8*† 74± 15‡
CI (L/min/m^2) Hypotension (n=18) No hypotension (n=44)	4.22± 1.26 4.44± 0.966	4.11± 1.06 4.49± 1.17	4.17± 1 4.41± .882	3.78± 1.13*† 4.45± 1.03
SVV% Hypotension (n=18) No hypotension (n=44)	11± 3.4 11.3± 4.5	13.3± 5* 10.5± 4	16± 3.12*† 11.9± 4.1	17.3± 5.2*† 11±3.7

CI: cardiac index, MAP: mean arterial pressure, SV: stroke volume, SBP: systolic blood pressure, SVV: stroke volume variations. T1: post-insufflation at tidalvolume 6mL/kg, T2: at tidal volume 8 mL/kg, T3: post-de-sufflation).*denotes statistical significance compared to the no-hypotension group. †denotes significance compared to the baseline reading within the hypotension group. ‡denotes significance compared to the baseline reading within the no-hypotension group.

Table 3: Accuracy of different variables in predicting hypotension

	AUC (95%CI)	Sensitivity	Specificity	PPV	NPV	Cutoff value
SVV8	0.799(0.677-0.921)*	72%	80%	59%	88%	>15%
Delta SVV	0.766(0.635-0.896)*	72%	77%	57%	87%	>3%
HR	0.679(0.543-0.816)*	89%	57%	46%	93%	>121 bpm
MAP	0.495 (0.328-0.662)	17%	95%	60%	74%	≤56 mmHg
Cardiac index	0.432 (0.266-0.597)	44%	75%	42%	77%	≤3.8 L/min/m^2

CI: confidence interval, HR: heart rate, MAP: mean arterial pressure, NPV: negative predictive value, PPV: positive predictive value, SVV: stroke volume variation.

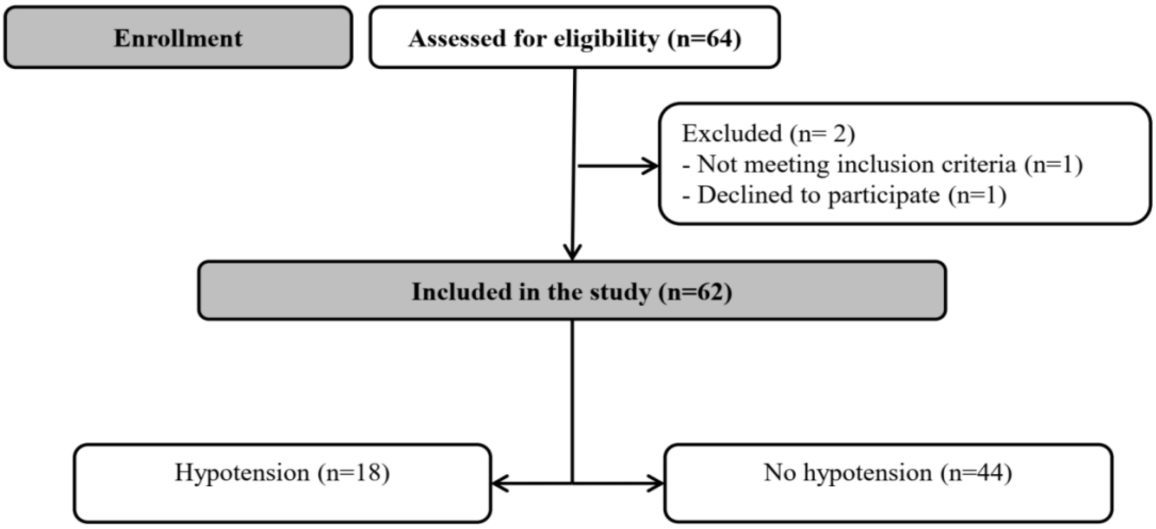

Figure 1: Flow chart showing patient recruitment.

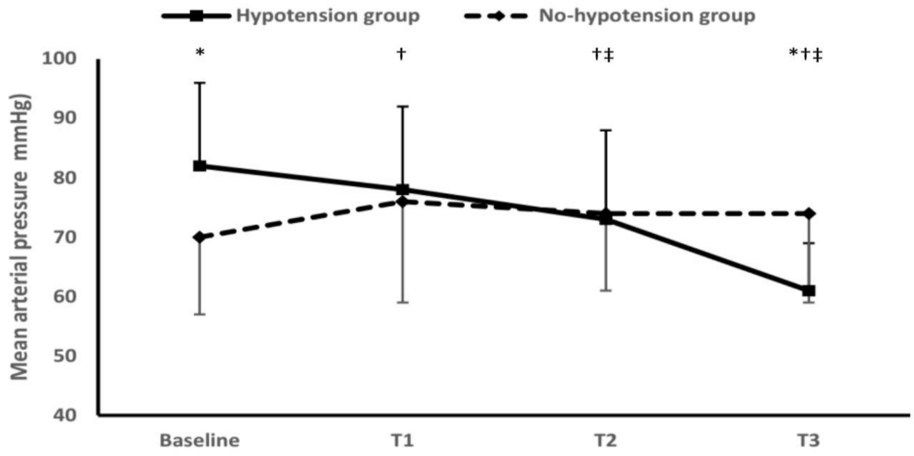

Figure 2: mean arterial pressure. T1: post-insufflation at tidal volume 6 ml/kg, T2: at tidal volume 8 mL/kg, T3: post-desufflation.*denotes significance between the two study groups. †denotes significance compared to the baseline reading within the hypotension group. ‡denotes significance compared to the baseline reading within the no-hypotension group.

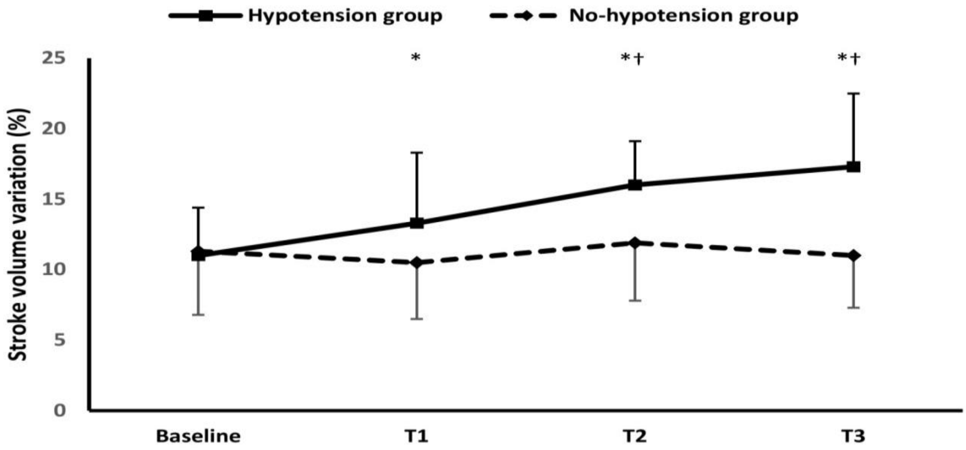

Figure 3: stroke volume variation. T1: post-insufflation at tidal volume 6 ml/kg, T2: at tidal volume 8 mL/kg, T3: post-desufflation. *denotes significance between the two study groups. †denotes significance compared to the baseline reading within the hypotension group.

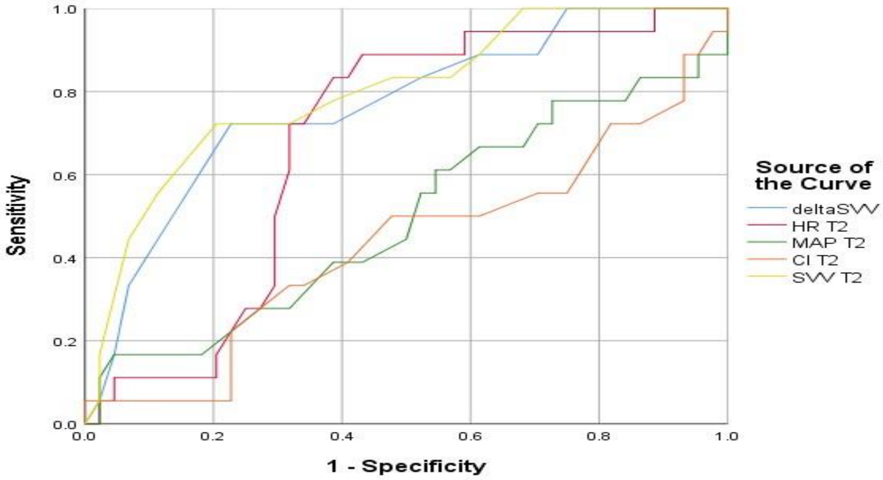

Figure 4: Receiver operating characteristic curve for the accuracy of different variables to predict hypotension. SVV: stroke volume variation, HR: heart rate, CI: cardiac index, MAP: mean arterial pressure

Discussion

The current study showed that electrical cardiometry-derived SVV can predict post-desufflation hypotension in children. The highest predictive properties were reported in SVV8 and delta SVV.

Pre-existent hypovolemia might contribute in the occurrence of post-desufflation hypotension **(11).** SVV is a well-known dynamic index for evaluation of the fluid responsiveness **(12).** SVV is a heart-lung interaction measure which depends on the cyclic variations in the stroke volume due to the changes in the venous return during positive pressure variation **(12).** SVV is increased in hypovolemic states. This explains the presence of high SVV, denoting relative hypovolemia, in patients who developed post-desufflation hypotension. The cutoff value of SVV in this study was > 15% and >3% for Delta SVV.

No previous studies were done to predict desufflation induced hypotension in pediatric patients with the use of SVV. However, a previous study had evaluated another dynamic index, namely the pulse oximetry plethysmographic waveform and its results are in line with our results **(6).**

Despite being not evaluated in pediatric population, the use of SVV for predicting hypotension during general anesthesia was evaluated in adults undergoing abdominal surgery **(9).** The AUC and optimal threshold value of pre-anesthetic SVV for prediction of decreased CO were 0.857 and 13%, respectively, the difference between these cutoff values and ours is probably due to the difference in population and the main objective (post-induction hypotension versus post-desufflation hypotension).

We found that delta SVV could accurately predict hypotension. The tidal volume challenge increased the accuracy of PPV and SVV in predicting fluid responsiveness in adults **(13-15).** And the cutoff values were 2.5% **(14)** which is close to our cutoff value 3%.

Another study evaluated the ability of TV challenge test in detecting fluid responsiveness in robot-assisted laparoscopic surgeries **(16)** and it reported a cutoff value >1% which is close to our results.

Hypotension is a serious perioperative complication which is associated with poor patient outcomes **(17).** The harms of hypotension would be more evident in vulnerable populations such as children. Therefore, early prediction of hypotension would help to provide prophylactic interventions such as fluid and/or vasopressor administration. Our findings provide the use of SVV, namely SVV8 and delta SVV, for predicting post-insufflation hypotension in children. We used electrical cardiometry-derived SVV which has the advantage of being non-invasive and accurate. Electrical cardiometry has another advantage for being economic compared to other cardiac output monitors, as it does not require costly consumables.

Our study has several limitations. It is a single centered study. We evaluated children with no cardiac morbidities. Most of the operations were general surgical procedures. Future studies are warranted to confirm our results in other interventions and populations.

Conclusion

Stroke Volume Variation and tidal volume challenge test can be useful tools to predict post-desufflation hypotension during pediatric laparoscopic surgery.

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