Effect of End-Tidal Carbon Dioxide Measurement on Resuscitation Efficiency and Termination of Resuscitation

End Tidal Karbonmonoksit Ölçümünün Resüsitasyon Etkinliği ve Sonlandırılması Üzerine Etkisi

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SUMMARY

Objectives

In this study, the value of end-tidal carbon dioxide ($ETCO_2$) levels measured by capnometry were evaluated as indicators of resuscitation effectiveness and survival in patients presenting to the emergency department with cardiopulmonary arrest.

Methods

$ETCO_2$ was measured after 2 minutes of compression or 150 compressions. $ETCO_2$ values were measured in patients that were intubated and in those who underwent chest compression. The following parameters were recorded for each patient: demographic data, chronic illness, respiration type, pre-hospital CPR, arrest rhythm, arterial blood gas measurements, $ETCO_2$ values with an interval of 5 minutes between the measurement and the estimated time of arrest, time to return to spontaneous circulation.

Results

Cardiac arrest developed in 97 cases, including 56 who were out of the hospital and 41 who were in the hospital. Fifty of these patients returned to spontaneous circulation, and just one of these had an initial $ETCO_2$ value below 10 mmHg. The mean of the final $ETCO_2$ levels was 36.4±4.46 among Patients who Return to Spontaneous Circulation (RSCPs) and 11.74±7.01 among those that died. In all rhythms; Asystole, pulseless electrical activity (PEA) and VF/VT; Overall, RSCPs had higher $ETCO_2$ levels than the cases who died. Among the PEA patients undergoing in-hospital arrests and those asystolic patients undergoing out of hospital arrest, the $ETCO_2$ values of the RSCPs were significantly higher than those of the cases who died.

Conclusions

$ETCO_2$ levels predicted survival as well as the effectiveness of CPR for patients who received CPR and were monitored by capnometry in the emergency department. As a result, we believe that it would be suitable to use capnometry in all units where the CPR is performed.

Key words: Capnography; capnometry; cardiopulmonary arrest; resuscitation.

ÖZET

Amaç

Çalışmamızda acil servise kardiyopulmoner arrest ile gelen hastalarda kapnometre ile ölçülen endtidal karbondioksit seviyelerinin uygulanan KPR'nin etkinliği ve hasta sağkalımının göstergesi olarak kullanılabileceğinin araştırılması amaçlandı.

Gereç ve Yöntem

Acil servisimize göğüs kompresyonuna başlanarak entübe edilen (acil ambulansla getirilmişse tüp kontrolü yapılan) ve gögüs kompresyonun ikinci dakikanın sonunda ya da 150 bası sonrası ilk ölçülen end-tidal karbondioksit ($ETCO_2$) değeri 0. dakika $ETCO_2$ olarak kabul edildi. Daha sonra beşer dakika ara ile $ETCO_2$ değerleri kaydedildi. Hastaların demografik verileri, kronik hastalık varlığı, 112 ile gelmişse neyle solutulduğu, hastane öncesi KPR uygulanması, hasta arrest ritmi, kan gazı değerleri, tahmini arrest süresi ile hastanın spontan dolaşımın dönme süresini içeren parametreler kaydedildi.

Bulgular

Çalışmaya alınan 97 olgunun 56'sı hastane dışı (HDKA), 41'i hastane içi gelişen arrest (HİKA) hastalardan oluşmaktaydı. Spontan dolaşıma geri dönen (SDGD) 50 olgudan sadece bir tanesinin ilk $ETCO_2$ düzeyi 10 mmHg nın altında olarak ölçüldü. Son ETCO2 düzeyi ortalamaları SDGD'lerde 36.4±4.46, hayatını kaybedenlerde 11.74±7.01 olarak bulundu. Asistoli, NEA, VF/VT ritimlerinin tamamında SGDG olgularında $ETCO_2$ düzeyleri exitus olanlardan yüksekti (p=0.001). Hastane içi nabızsız elektriksel aktivite (NEA) hastaların ve hastane dışı asistolik hastaların, SDGD olgularında $ETCO_2$ değerleri eksitus olan olguların $ETCO_2$ değerlerinden yüksekti.

Sonuç

Acil servislerde KPR uygulanan ve kapnometre ile izlenen hastalarda $ETCO_2$ düzeyi sağ kalım, KPR'nin etkinliği ve devamı açısından yol göstericidir bu yüzden KPR uygulanan tüm birimlerde kapnometre kullanımının uygun olacağını düşünüyoruz.

Anahtar sözcükler: *Kardiopulmoner arrest; kapnometre; resüsitasyon.*

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Introduction

Modern cardiopulmonary resuscitation (CPR) began with airway opening methods by Peter Safar in 1959 and external cardiac compression by William Kouwen hoven in 1960. However, resuscitation trials have been reported for several centuries.[1,2] Since modern resuscitation applications have been used, researchers have been studying ways to prevent cardiac arrest and have been working to develop effective resuscitation techniques.

Capnometry is a method used to verify the accuracy of the endotracheal tube placement in cardiopulmonary arrest patients.[3] High end-tidal carbon dioxide ($ETCO_2$) level measurements by capnometry may be important to successful resuscitations.[4-6] In this study, we aimed to investigate the effect of quantitative $ETCO_2$ measurement with capnometry during CPR to determine the effectiveness of CPR and patient prognosis in cardiopulmonary arrest patients.

Materials and Methods

After obtaining approval from the ethics committee and conforming to the provisions of the Declaration of Helsinki in 1995 (as revised in Seoul 2008), non-traumatic out-of hospital and in-hospital cardiopulmonary arrest patients over 18 years of age were enrolled in this cross-sectional study between February 1, 2012 and June 30, 2012.

Resuscitations were performed according to the American Heart Association (AHA) Advanced Cardiac Life Support (ACLS) guidelines. $ETCO_2$ levels were measured and the time of admission to the emergency department was noted as was the time of intubation. $ETCO_2$ values were recorded after the 6th ventilation in patients who underwent cardiopulmonary arrest during the emergency service follow-up. $ETCO_2$ levels were measured and noted in five minute intervals starting at the time of resuscitation. Resuscitation time was determined by the responsible doctor who managed the resuscitation. Patients who underwent a second cardiopulmonary arrest and were resuscitated were excluded from the study.

The patients were divided into two groups: 1. Exitus patients (EP), and 2. Returned to spontaneous circulation patients (RSCP). Demographic data, chronic disease, ventilation method in the ambulance, out-of hospital CPR application, arrest rhythm, blood gases, $ETCO_2$ levels recorded at intervals of five minutes, predicted arrest time period and return time of spontaneous circulation were recorded. Patients brought by ambulance who then underwent cardiac arrest in the emergency department were accepted as in-hospital cardiac arrest patients.

We used a standard capnography device (Medilab Cap 10) for $ETCO_2$ measurements.

SPSS 15.0 for Windows program was used for statistical evaluation. Chi square test and Fisher's exact test was used to compare data between groups. One Way Anova and independent sample T-tests were used for parametric variables. Kruskal Wallis and Mann Whitney U tests were used to compare nonparametric variables. Results were considered statistically significant at $p<0.05$.

Results

In our study, 37 (38.1%) of the 97 patients were female, and 60 (61.9%) were male. The mean age of the males was 66.75±13.84 years (min: 56, max: 89) and was 71.57±11.52 years (47-87) for females. The overall mean age of males and females combined was 68.59±13.15 years (26-89). The ages of the males and females were not significantly different ($p>0.05$).

Forty-one (42.3%) patients were In-hospital cardiac arrest patients (IHCAP) and 56 (55.7%) were Out-hospital cardiac arrest patients (OHCAP). Twenty two (75%) of the in-hospital arrest patients died and 19 (72%) of them returned to spontaneous circulation. Twenty-five (66.64%) out-of hospital patients (OHCAP) died and 31 (63.55%) returned to spontaneous circulation. The mean ages of the patients who died and those who returned to spontaneous circulation were not significantly different ($p>0.05$).

Survival due to ventilation techniques (Laryngeal Mask Airway, Bad Valve, Combitube, etc.) performed on patients in the ambulance before admission to the emergency department admission of the IHCAPs and OHCAPs were not significantly different ($p>0.05$).

In our study ages of 72 (74.6%) patients were over 60 years of age. Seventy-one (73.2%) patients were brought to our emergency department by ambulance. There were no significant differences in the survival of the groups with regards to admission time, arrival by ambulance, location of cardiac arrest, and the diagnosis and presence of chronic disease ($p>0.05$). However, the survival of the patients with regards to arrest time period were significantly different ($p<0.05$).

CPR application ratios were not significantly different between the groups in OHCAPs ($p>0.05$). Survival due to arrest rhythm ($p<0.05$) and arrest time period ratios ($p<0.05$) were significantly different between groups ($p=0.001$). Eighty-one percent of asystole patients, 36% of pulseless electric activity (PEA) patients and 58% of the VF/VT patients died.

The exitus cases' arrest rhythms were 36.2% (n=17) asystole, 40.4% (n=19) PEA, and 23.4% (n=11) VF/VT. Of 50 RSCPs, 27

(54%) returned to spontaneous circulation in the first 15 minutes, 37 (74%) in first 20 minutes and 45 (90%) in the first 30 minutes.

The mean first $ETCO_2$ measurement of RTSC patients was 18.6±9.13 and the mean final $ETCO_2$ was 36.4±4.46. The mean first $ETCO_2$ value of exitus patients was 15.91±8.35 and the mean final $ETCO_2$ value was 11.74±7.06 mm/Hg.

The difference between the first $ETCO_2$ (18.6±9.13) and the last $ETCO_2$ (36.4±4.46) levels were significantly different in RSCPs ($p<0.05$) and in EPs ($p<0.05$).

The $ETCO_2$ levels of RSCPs varied between 26-48 mmHg (mean: 36.4±4.46). Age ($p<0.05$) and 45th min $ETCO_2$ levels ($p<0.05$) of IHCAPs were higher than those of the OHCAPs in the EP group. The mean age of the IHCAPs was 75.0±7.0 years (57-87) and this value was 66.64±14.56 years (26-87) for OHCAPs. In the RSCP group, age ($p<0.05$), and the first ($p<0.05$), 5th ($p<0.05$), 10th ($p<0.05$), and 20th ($p<0.05$) $ETCO_2$ levels were significantly higher in IHCAPs than in OHCAPs (Table 1).

There were significant differences between the EP and RSCP groups with regards to gender, admission time, arrest rhythm, chronic disease and ventilation technique in the ambulance according to arrest place (in hospital/out-of hospital) (Table 2).

$ETCO_2$ levels of the RSCP group ranged between 26-48 mmHg (36.4±4.46), and this level for the EP group was 2-23 mmHg (11.74±7.01). The final $ETCO_2$ level was related with survival ($p<0.05$).

In the asystole patients, the 15th, 20th, and 25th min $ETCO_2$ (p=0.009, p=0.028, p=0.033) levels were higher in RSCPs than in EPs. In PEA patients, the 10th, 15th, 20th, and 30th min $ETCO_2$ values (p=0.002, p=0.001, p=0.002, p=0.005) were higher in RSCPs than EPs, and in VF/VT patients, the 15th and 30th min $ETCO_2$ values (p=0.044, p=0.038) were higher in RSCPs than in EPs (Table 3).

In the IHCAPs, the PEA patients' first, 5th, 10th, 15th, 20th and 30th min $ETCO_2$ levels (p=0.034, p=0.014, p=0.001, p=0.001, p=0.002, p=0.013) were higher in RSCPs than EPs (Table 4). In the OHCAPs, the asystolic patients' 15th, 20th and 25th min $ETCO_2$ levels (p=0.011, p=0.033, p=0.038) were higher in RSCPs than in EPs (Table 5).

The 5th, 10th, 15th, 20th, 25th, 30th, 35th, 40th and 45th min $ETCO_2$ levels (p=0.001, p=0.001, p=0.001, p=0.001, p=0.001, p=0.001, p=0.003, p=0.001, p=0.030) of EPs were lower than those of the RSCPs. The mean final $ETCO_2$ level of RSCPs was 36.4±4.46 mmHg.

Discussion

Cardiopulmonary arrest cases are common in the emergency department and should be attended to immediately. Cardiopulmonary arrest can result in death without rapid and effective intervention.[7] Survival decreases 6-7% per minute in patients that did not undergo chest compression.[8,9]

The IHCAPs' rate of return to spontaneous circulation is high because they are diagnosed early. However, most of these patients are elderly so mortality does not decrease.[10] In our study, 56 (58%) of 97 cases were OHCAPs.

Survival is related with pre-hospital factors in OHCAPs.[11-13] These factors include arrival time, basic life support education of the general public and medical service personnel,

Table 1. Age and $ETCO_2$ level distributions of RSCPs and EPs according to place of arrest

	Arrest place						Total			*p*
	In-hospital			Out-of-hospital						
	Mean±SD	**Min.**	**Max.**	**Mean±SD**	**Min.**	**Max.**	**Mean±SD**	**Min.**	**Max.**	
EPs										
Age	75.0±7.0	57	87	66.64±14.56	26	87	70.55±12.28	26	87	0.038
$ETCO_2$ 45 min	22.5±6.36	18	27	9.25±4.5	4	18	11.9±7.17	4	27	0.044
RSCPs										
Age	71.95±12.4	47	89	63.55±13.81	39	86	66.74±13.79	39	89	0.047
$ETCO_2$ 0 min	24.47±8.79	5	36	15±7.38	3	35	18.6±9.13	3	36	0.001
$ETCO_2$ 5 min	25.84±7	6	35	19.13±5.89	7	35	21.68±7.08	6	35	0.001
$ETCO_2$ 10 min	30.17±8.33	18	44	23.57±7.86	13	48	26.04±8.58	13	48	0.011
$ETCO_2$ 20 min	33.88±8.64	20	43	25±7.57	14	36	28.09±8.88	14	43	0.023

Table 2. Gender, arrival time, arrest rhythm and chronic disease ratio distribution of RSCPs and EPs according to place of arrest

	Arrest place				Total		*p*
	In-hospital		Ou-of-hospital				
	n	%	n	%	n	%	
EPs							
Gender							
Female	8	47.1	9	52.9	17	36.2	0.979
Male	14	46.7	16	53.3	30	63.8	
Arrival time							
00:01-04:00	2	28.6	5	71.4	7	14.9	0.486
04:01-08:00	1	25.0	3	75.0	4	8.5	
08:01-12:00	9	69.2	4	30.8	13	27.7	
12:01-16:00	4	44.4	5	55.6	9	19.1	
16:01-20:00	4	44.4	5	55.6	9	19.1	
20:01-24:00	2	40.0	3	60.0	5	10.6	
Arrest rthyhm							
Asistoli	1	5.9	16	94.1	17	36.2	0.001
NEA	18	94.7	1	5.3	19	40.4	
VF/VT	3	27.3	8	72.7	11	23.4	
Arrest time period							
0 min	22	100.0	0	0.0	22	46.8	0.001
0-5 min	0	0.0	2	100.0	2	4.3	
6-10 min	0	0.0	7	100.0	7	14.9	
11-15 min	0	0.0	13	100.0	13	27.7	
16-20 min	0	0.0	3	100.0	3	6.4	
Chronic disease							
No	7	43.8	9	56.3	16	34.0	0.763
Yes	15	48.4	16	51.6	31	66.0	
RSCPs							
Gender							
Female	8	40.0	12	60.0	20	40.0	0.812
Male	11	36.7	19	63.3	30	60.0	
Arrival time							
00:01-04:00	1	16.7	5	83.3	6	12.0	0.716
04:01-08:00	1	20.0	4	80.0	5	10.0	
08:01-12:00	2	33.3	4	66.7	6	12.0	
12:01-16:00	4	40.0	6	60.0	10	20.0	
16:01-20:00	5	50.0	5	50.0	10	20.0	
20:01-24:00	6	46.2	7	53.8	13	26.0	
Arrest rthyhm							
Asistoli	0	0.0	4	100.0	4	8.0	0.006
NEA	18	52.9	16	47.1	34	68.0	
VF/VT	1	8.3	11	91.7	12	24.0	
Arrest time period							
0 min	18	100.0	0	0.0	18	36.0	0.001
0-5 min	1	6.3	15	93.8	16	32.0	
6-10 min	0	0.0	10	100.0	10	20.0	
11-15 min	0	0.0	4	100.0	4	8.0	
16-20 min	0	0.0	2	100.0	2	4.0	
Chronic disease							
Yok	5	35.7	9	64.3	14	28.0	0.836
Var	14	38.9	22	61.1	36	72.0	

Table 3. $ETCO_2$ levels of arrest rthyms' according to survival

	EPs		RSCPs		Total		*p*
	n	Mean±SD	n	Mean±SD	n	Mean±SD	
Arrest rthyhm = Asystoly							
15 min	17	12.82±7.64	4	23.75±4.57	21	14.9±8.32	0.009
20 min	17	12.12±8.08	3	25.67±7.02	20	14.15±9.21	0.028
25 min	14	10.36±5.92	2	31±16.97	16	12.94±9.96	0.033
Arrest rthyhm = PEA							
10 min	19	16.84±8.29	33	26.39±9.18	52	22.9±9.94	0.002
15 min	19	16.84±7.75	25	27.28±8.87	44	22.77±9.82	0.001
20 min	19	16.58±8.66	16	29.31±9.56	35	22.4±11.02	0.002
Arrest rthyhm = VF/VT							
15 min	11	18.45±6.36	7	28.29±9.76	18	22.28±9.04	0.044
30 min	11	13.45±6.67	3	29.33±9.07	14	16.86±9.62	0.038

Table 4. $ETCO_2$ levels of arrest rthyms' in IHCAPs according to survival

	EPs				RSCPs				Total				*p*
	n	Mean±SD	Min.	Max.	n	Mean±SD	Min.	Max.	n	Mean±SD	Min.	Max.	
Arrest rthyhm = PEA													
0 min	18	18.56±8.1	5	34	18	24.22±8.974	5	36	36	21.39±8.9	5	36	0.034
5 min	18	18.56±8.09	5	30	18	25.39±6.912	6	35	36	21.97±8.19	5	35	0.014
10 min	18	17.56±7.91	5	33	17	30.12±8.587	18	44	35	23.66±10.32	5	44	0.001
15 min	18	17.5±7.41	6	31	12	30.42±6.788	20	40	30	22.67±9.54	6	40	0.001
20 min	18	17.28±8.34	5	31	7	34.43±9.181	20	43	25	22.08±11.5	5	43	0.002
30 min	16	17.31±7.64	4	32	2	35±1.414	34	36	18	19.28±9.18	4	36	0.013

Table 5. $ETCO_2$ levels of arrest rthyms' in OHCAPs according to survival

	EPs				RSCPs				Total				*p*
	n	Mean±SD	Min.	Max.	n	Mean±SD	Min.	Max.	n	Mean±SD	Min.	Max.	
Arrest rthyhm = Asystoly													
15 min	16	13.31±7.61	3	29	4	23.75±4.573	19	30	20	15.4±8.21	3	30	0.011
20 min	16	12.69±7.98	2	31	3	25.67±7.024	19	33	19	14.74±9.07	2	33	0.033
25 min	13	10.85±5.86	2	24	2	31±16.971	19	43	15	13.53±10.01	2	43	0.038

presence of resuscitation centers, and the presence of automatic external defibrillator in public places.

The duration between the time of cardiac arrest and alerting the emergency medical service is the first step of survival, and is directly related to the long term prognosis of cardiac arrest patients. One study reported that survival significantly decreased if the emergency service was not called within 6 minutes in OHCAPs.[14] In our study, there was a significant difference between survival ratios of the groups according to the period between arrest and the call to emergency services.

In the meta-analysis by Sasson et al, although 53% (n=75.800) of 143.000 cases were reported as witnessed arrest cases, only 32% (n=24.250) of the cases were resuscitated at the arrest place by a rescuer.[15] In our study, 13 cases who were not brought to the hospital in an ambulance did not undergo cardiopulmonary resuscitation before arrival. Survival has been reported to be less than 5% in OHCAPs.[16] In our hospital, survival was 32% (n=31) in OHCAPs.

In OHCAPs, low survival is related with the presence of asystole and PEA as the first rhythm.[16,17] In our study, there was no significant difference between the RSCP and EP groups according to arrest rhythm and arrest time period in IHCAPs. However, there was a significant difference between these groups in OHCAPs. In OHCAPs, 80% of asystolic patients died, while 94.1% of PEA patients and 57.9% of VF/VT patients returned to spontaneous circulation.

Similar to the study by Takei et al.,[14] we also found a relationship between arrest time period and survival. Return to spontaneous circulation rate decreases and exitus ratio increases with a longer arrest time period. Mortality was high in asystole and PEA.

In our study, 27 (54%) of 50 cases returned to spontaneous circulation within the first 15 mins, 37 (74%) returned in the first 20 mins, and 45 (90%) patients returned in the first 30 mins. The return to spontaneous circulation ratio decreased with longer cardiopulmonary resuscitation times.

Hodgetts et al reported that survival of IHCAPs was high.[18] The presence of a chronic disease negatively effects survival, and the best chances at survival are provided with early defibrillation.[19] In our study, when we considered the arrest places of the EPs, age and 45th min $ETCO_2$ levels of IHCAPs were significantly higher than those of OHCAPs. In RSCPs, the first, 5th, 10th and 20th min $ETCO_2$ levels of IHCAPs were higher than those of OHCAPs. Similar to the literature, in our study, the $ETCO_2$ level of RSCPs varied between 26-48 mmHg (36.4±4.46).[20]

A sudden increase in $ETCO_2$ indicates the return to spontaneous circulation.[4-6] White reported that rhythm changes and $ETCO_2$ levels can be used as an early indication of pulmonary perfusion even in pulseless cases, but only in OHCAPs.[21] Also, a relationship between coronary perfusion pressure and $ETCO_2$ has been reported.[22,23] If $ETCO_2$ remains under 10 mmHg for a long time during CPR, it is quite likely that a return to spontaneous circulation will not occur.[24-28] One study reported that just one case survived whose $ETCO_2$ level remained under 10 mmHg.[29] In our study, just one of the RSCPs' $ETCO_2$ levels was under 5 mmHg. Similar to the literature, we found a relationship between final $ETCO_2$ level and survival.

Heradstveit et al reported significant differences between RSCPs and $ETCO_2$ in all asystole, PEA, and VF/VT rhythms.[30] When we grouped cases according to arrest rhythms, the 15th, 20th, and 25th min $ETCO_2$ levels of asystole patients, the 10th, 15th, 20th, and 30th min $ETCO_2$ levels of PEA patients, and the 15th and 30th min $ETCO_2$ levels of VF/VT patients were higher in RSCPs than in EPs. When we considered the IHCAPs according to arrest rhythm, the first, 5th, 10th, 15th, 20th and 30th min $ETCO_2$ levels of PEA patients were higher in RSCPs than in EPs. In OHCAPs, the 15th, 20th and 25th min $ETCO_2$ levels of asystole patients were higher in RSCPs than in EPs.

Conclusion

As suggested in the guidelines, $ETCO_2$ follow-up of the cardiopulmonary arrest patients with capnography would be helpful in the continuation of CPR and in predicting the survival of the patient. Capnography use is suitable in emergency services and in ambulances.

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Limitations

Patients were excluded if they underwent a second cardiopulmonary arrest, and this limited our study, as we could not determine the effectiveness of ETCO2 measurements in these patients.

Conflict of Interest

The authors declare that there is no potential conflicts of interest.

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