Comparison of Two Different Commonly Used Venous Cannulae in Patients Undergoing Coronary Artery Bypass Grafting for Multivessel Disease

Koroner Baypas Cerrahi Uygulanan Çok Damar Hastalığında Yaygın Olarak Kullanılan İki Farklı Venöz Kanülün Karşılaştırılması

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ABSTRACT Objective: To investigate the flow differences between two types of venous cannulae. **Material and Methods:** 60 patients were included into this study. They were divided into two groups. Cannulation in the first group, Two Stage (TS) Group (n=30), was done with a two stage venous cannula. The second group, Single Stage (SS) Group (n=30), were cannulated with a single stage venous cannula. Initial pump flows were noted separately for each patient before cardiopulmonary bypass grafting (CPBG) and all the flow rate changes during distal anatomoses to the circumflex (Cx) and/or right coronary arteries (RCA) were recorded. Mixed venous oxygen saturations were also established. **Results:** Pump flows in the TS group had decreased in most of the patients (96.7%) during the distal anastomosis of the Cx and/or RCA. Mixed venous oxygen saturations were also found significantly as lower. No pump flow reduction was needed in the SS group during the revascularization of the same anatomic areas. There were no noticeable changes in their mixed venous oxygen saturations. When the changes in the flow rates and venous oxygen saturations of the two groups were compared the results were statistically significant ($p< 0.001$ and $p< 0.05$ respectively) (TS group SVO2: 69.066 ± 4.290 and SS group SVO2: 72.433.±.7.156). **Conclusion:** Patients undergoing CABG with mild hypothermia usually do not present with postoperative ischemic manifestations but patients with severe preoperative peripheral, carotid, renal, intestinal and/or pulmonary problems may suffer from ischemia due to flow changes during CPBG. Using a single stage venous cannula for the patients with multivessel coronary disease and especially with accompanying comorbidities may help in maintaining the calculated flow rates hence perfusion.

Key Words: Cardiopulmonary bypass; coronary arterial disease; coronary arterial bypass grafting

ÖZET Amaç: İki tip venöz kanül arasındaki akım farklarını araştırmak. **Gereç ve Yöntemler:** Çalışmaya 60 hasta dahil edilmiş ve hastalar iki gruba ayrılmıştır. Birinci grup; Two Stage (TS) grup (n=30), venöz kanülasyon two stage kanül ile yapılmıştır. İkinci grup; Single Stage (SS) grup (n=30), venöz kanülasyon single stage kanül ile yapılmıştır. Kardiyopulmoner baypas öncesindeki başlangıç pompa akımı sirkumfleks (Cx) ve/veya sağ koroner arter (RCA) distal anastomozları sırasındaki pompa akım değişiklikleri, her hasta için ayrı ayrı kayıt edilmiştir. Aynı zamanda her hastanın mixed venöz oksijen satürasyonları da ölçülerek değerlendirilmiştir. **Bulgular:** TS grubundaki hastaların çoğunda (%96.7), Cx ve/veya RCA distal anastomozları sırasında pompa akımı azalmıştı ve mixed venöz oksijen satürasyonları anlamlı derecede daha düşük bulunmuştur. SS grubunda ise aynı bölgeye yapılan distal anastomozlar sırasında pompa akımının düşürülmesine ihtiyaç kalmamış ve mixed venöz oksijen satürasyonu değerlerinde değişiklik olmamıştır. İki grup arasında, pompa akım oranlarındaki ve venöz oksijen satürasyonlarındaki değişiklikleri karşılaştırdığımız zaman istatistiksel olarak anlamlı fark bulunmuştur (sırasıyla $p< 0.001$ ve $p<0.05$) (TS grup SVO2: 69.066 ± 4.290 ve SS grup SVO2: 72.433 ± 7.156). **Sonuç:** Orta derecede hipotermi uygulanarak koroner baypas yapılan hastalarda postoperatif ortaya çıkan iskemik olaylar sık görülmemekle birlikte, preoperatif ciddi periferal, karotid, renal, intestinal veya pulmoner problemleri olan hastalar, kardiyopulmoner baypas sırasındaki akım değişikliklerinden kaynaklanan iskemiden etkilenebilirler. Özellikle yandaş hastalıkları da bulunan çoklu koroner arter hastalarında single stage venöz kanül kullanımı, doku hipoperfüzyonuna yol açmadan pompa akımının yönetilmesine yardımcı olabilir.

Anahtar Kelimeler: Kardiyopulmoner baypas, koroner arter hastalığı; koroner arter baypas greftleme

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The term "physiology" was coined by a Dutch physician, Boerhaave, to describe the study of interdependent organ functions under normal conditions. Extracorporeal circulation (EC) imposes several conditions which lead to a series of changes in normal organ functions. Therefore, the physiological functions under these conditions differ considerably in comparison with the normal conditions.[1]

One of the essential components of the heart-lung machine is the venous cannula that helps to retrieve blood from the point of venous return at the heart (namely the right atrium) to the venous reservoir attached on the machine.[2] The number and types of the venous cannulae differ according to the type of the operation to be accomplished and to the preference of the operating surgeon. Atrio-caval cannulation of the right atrium with a single venous cannula is one of the options that can be used for the accomplishment of coronary artery bypass grafting (CABG) operations.

Two stage venous cannulae are often the frequently preferred cannulae for atrio-caval cannulation during CABG surgery. Despite they are claimed to perform better in tems of flow characteristics in comparison with the single stage venous cannulae[3] we however noticed a decline in the venous return during the surgery performed on the obtuse margin of the heart when the apex was deviated and fixed to the opposite side. The alternative to the two stage venous cannula is the single stage cannula which is also widely used.[3] In this prospective study we investigated the differences in the flow characteristics of the two cannulae (two-stage versus single-stage venous cannula) during the revascularization of the multiple vessels, including especially the obtuse margin branches of the Cx artery and the RCA, and their effects on the mixed venous oxygen saturations (SVO_2) and arterial oxygen saturations during cardiopulmonary bypass.

MATERIAL AND METHODS

The patients were informed about the study and a written consent was obtained from each patient. As both single stage and two stage cannulae are widely and routinely used in cardiopulmonary bypass applications all over the world and neither a new methodology nor a new application was concerned no ethics committee approval was thought to be necessary and hence we did not apply for an approval.

Sixty consecutive coronary artery diseased but otherwise healthy patients were recruited for this investigation that had to have a bypass graft on at least either one of the Cx or the RCA. All patients were operated by a single surgeon under extracorporeal circulation. The demographic characteristics of the patients in either groups were comparable (Table 1). Patients were divided into two groups. In the first group, which consisted of 30 patients, the atrio-caval cannulation was done with a two stage venous cannula (CalMed dual stage venous return catheter REF:XDS-11140 LOT:12130708) and the group was named as the TS Group (Figure 1A). The second group was also consisted of 30 patients and they were cannulated with a single stage venous

TABLE 1: Demographic presentation of the patients in both groups. TS: Two Stage, SS: Single Stage.

	TS Group	SS Group	P value
Female	8 (26.6%)	10 (33.3%)	0.573
Men	22 (73.4%)	20 (66.7%)	0.614
Age (mean)	65.3 ± 2.6	65.7 ± 3.2	0.661
Number of distal anastomosis	3.00 ± 0.46	3.10 ± 0.76	0.538
Smoking	22 (73.4%)	20 (66.7%)	0.614
Hypertension	24 (80%)	23 (76.6%)	0.750
Type II diabetes mellitus	11 (36.6%)	8 (26.6%)	0.408

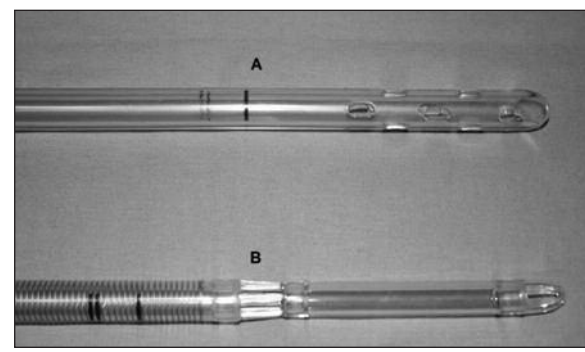

FIGURE 1 A: Single stage venous cannula.
B:Two stage venous cannula.

cannula (CalMed venous return catheter-straight Ref:RV-40026 LOT:17180608), hence the group was named as the SS Group (Figure 1B). Initial pump flows were noted separately for each patient at the commencement of cardiopulmonary bypass and all the flow rate changes during distal anastomoses to the Cx and/or RCA were recorded. Synchronously mixed venous oxygen saturations were also estimated. The recorded peroperatory parameters and the changes noted in these parameters throughout the operation were given in Table 2 and Table 3.

STATISTICS

Demographic data were expressed as mean±standard deviation (SD) for continuous variables and as numbers and percentages [n(%)] for categorical variables. All tests were 2-sided, and alpha was set at = 0.05. All analyses were performed with SPSS (version 13.0, SPSS, Inc., Chicago, IL) software package. The continuous variables and the categorical variables were compared between the groups using the two independent-variables t test and chi-square or Fisher's Exact test.

TABLE 2: Parameters recorded peroperatively in patients in the TS Group.

Number of the patient	Temperature (°C)	Number of the distal anastomosis	Venous oxygen saturation (%)	Arterial oxygen saturation (%)	During the distal anastomoses period	Decrease in venous return (cc)	Flow rate
1	30-35	3	68-47	92-87	PDA	200	3/4
2	30-35	3	78-76	93-83	RCA-Cx	250	3/4
3	30-35	3	71-68	93-89	RCA	350	3/4
4	30-35	3	68-60	99-89	RCA	300	3/4
5	30-35	3	67-62	91-89	RCA	400	2/4
6	30-35	3	60-56	91-87	RCA	250	3/4
7	30-35	2	73-73	93-88	Cx	300	3/4
8	30-35	3	75-60	99-90	PDA	550	2/4
9	30-35	3	72-61	98-89	RCA	450	2/4
10	30-35	3	67-63	96-89	RCA	450	2/4
11	30-35	3	71-68	98-96	RCA	100	4/4
12	30-35	4	60-58	94-93	RCA+Cx	450	2/4
13	30-35	3	64-62	91-90	RCA	350	3/4
14	30-35	4	67-56	90-88	RCA+Cx	150	3/4
15	30-35	3	68-64	97-91	RCA+Cx	350	2/4
16	30-35	3	72-60	97-81	RCA	400	2/4
17	30-35	3	70-67	96-90	RCA	300	3/4
18	30-35	3	73-68	98-92	RCA	300	3/4
19	30-35	3	70-61	97-88	RCA	300	3/4
20	30-35	3	76-70	99-94	RCA	200	3/4
21	30-35	2	69-65	96-90	Cx	350	3/4
22	30-35	3	74-68	98-94	RCA	250	3/4
23	30-35	4	68-56	94-90	RCA+Cx	450	2/4
24	30-35	3	68-62	97-92	RCA	300	3/4
25	30-35	2	66-61	95-90	RCA	350	3/4
26	30-35	3	71-64	97-92	RCA	300	3/4
27	30-35	3	64-59	95-91	RCA	300	3/4
28	30-35	3	68-62	95-89	RCA	300	3/4
29	30-35	3	71-66	99-93	RCA+Cx	350	3/4
30	30-35	3	63-57	98-89	PDA	400	2/4

TABLE 3: Parameters recorded peroperatively in patients in the SS Group.

Number of the patient	Temperature (°C)	Number of the distal anastomosis	Venous saturation (%)	Arterial saturation (%)	During the distal anastomoses period	Decrease in venous return (cc)	Flow rate
1	30-35	2	73-73	99-98	RCA	No	4/4
2	30-35	2	69-65	98-96	RCA	No	4/4
3	30-35	4	68-56	99-94	RCA+Cx	No	4/4
4	30-35	4	65-69	97-89	RCA+Cx	No	4/4
5	30-35	2	80-75	92-86	RCA	No	4/4
6	30-35	3	78-63	94-87	RCA	No	4/4
7	30-35	3	62-66	84-72	RCA	No	4/4
8	30-35	3	72-68	99-87	RCA+Cx	No	4/4
9	30-35	3	62-58	89-79	RCA	No	4/4
10	30-35	3	72-69	100-98	RCA	No	4/4
11	30-35	4	68-66	100-97	RCA+Cx	No	4/4
12	30-35	4	62-60	93-84	RCA+Cx	No	4/4
13	30-35	3	71-63	97-88	RCA	No	4/4
14	30-35	4	60-62	94-88	RCA+Cx	No	4/4
15	30-35	3	80-71	87-74	RCA	No	4/4
16	30-35	3	73-72	99-96	RCA	No	4/4
17	30-35	3	71-68	84-82	RCA	No	4/4
18	30-35	3	83-76	96-89	D2	100	4/4
19	30-35	2	71-63	96-90	RCA	No	4/4
20	30-35	4	61-59	87-69	RCA+Cx	No	4/4
21	30-35	4	80-67	98-99	RCA+Cx	No	4/4
22	30-35	3	80-74	92-87	RCA	No	4/4
23	30-35	2	70-61	96-90	RCA	No	4/4
24	30-35	4	83-57	91-78	Cx	150	4/4
25	30-35	3	72-68	99-98	OM1	100	4/4
26	30-35	2	69-68	97-91	RCA	No	4/4
27	30-35	4	70-67	81-87	RCA+Cx	No	4/4
28	30-35	3	80-69	91-99	RCA	No	4/4
29	30-35	2	80-67	99-87	RCA	No	4/4
30	30-35	4	86-67	99-100	RCA+Cx	No	4/4

Nonparametric Mann Whitney U test was used for comparing the groups due to the irregularity in the distribution of the groups.

RESULTS

In the TS Group patients, pump flows were reduced almost in all but 1 (96.7%) patient during the distal anastomosis period to the Cx and/or RCA. In 9 patients (30%) pump flow had to be lowered to ½ of the standard and in 20 (66.7%) patients it had to be lowered to ¾ of the standard flows due to reduced venous return. When this decline was compared with the SS group, the results turned out to be statistically significant as no pump flow reduction was needed in the SS group patients during the distal anastomosis times to the Cx and/or RCA ($p< 0.001$). Mixed venous oxygen saturations of the patients were also significantly lowered in whom the pump flows had to be reduced (TS group SVO_2: 69.066 ± 4.290 and SS group SVO_2: 72.433 ± 7.156). When this reduction in the mixed venous oxygen saturations of the TS group was compared with the mixed venous oxygen saturation fluctuations in the SS Group patients it was also found to be statistically significant ($p< 0.05$).

The clinical outcomes for all the patients in both groups were uneventful but these patients had no extra comorbidities.

DISCUSSION

Mixed venous oxygen saturation is commonly used to assess the balance of total body oxygen delivery to oxygen demand during CPBG. Major postoperative complications potentially secondary to inadequate oxygen delivery during CPBG indicate that mixed venous oxygen saturation may not detect regional venous desaturation during CPBG. Profound regional venous desaturation and progressive regional acidemia may go undetected even when a standard pump flow rate of 100 mL.kg-1.min-1 is used and mixed venous oxygen saturation is normal.[4]

In addition to CPBG flow rates, perfusion pressure during CPBG is an important determinant of adequate nutrient delivery to vascular bed. Perfusion pressure is determined by the interaction of blood flow and overall arterial resistance.[5]

Continuous monitoring of the hematocrit and SVO_2 provides evidence-based guidelines for safe cardiopulmonary bypass. The lower limits of critical range for a safer cardiopulmonary bypass are hematocrit of 12% and SVO_2 of 46%.[6]

In clinical practice, when body temperature is at 28°C or greater, a flow of 2.5 L/min/m^2 is usually chosen for infants and children younger than about 4 years of age and a flow of 2.2 L/min/m^2 for older patients. For adults with a body surface area of 2.0 m^2 or more, a flow of 1.8 to 2.0 L/min/m^2 may be chosen, to avoid the disadvantages of high flow through the oxygenator. When moderate hypothermia is chosen, the CPBG flow can safely be reduced to about 1.7 L/min/m^2 for prolonged periods.[7]

Mixed venous oxygen saturation (SVO_2) assesses the relationship between oxygen delivery (DO_2) and oxygen consumption (VO_2); values below 60% indicate inadequate oxygen delivery. Because of differences in regional vascular tone, higher SVO_2 does not assure adequate oxygen delivery to all vascular beds.[4,8] Metabolic acidosis or elevated lactic acid levels also indicate inadequate perfusion.

It is known that renal failure increases the morbidity and mortality in patients undergoing cardiac surgery. Careful preoperative management and intraoperative techniques, such as avoiding low perfusion pressure and using low-dose dopamine, may be useful for a good operative outcome.[9]

The incidence of acute renal failure (ARF) is dependent on the particular type of CPBG and surgery. Typical coronary artery bypass grafting has the lowest incidence of ARF (approximately 2.5%) and ARF that requires dialysis (ARF-D) (approximately 1%), followed by valvular surgery with an incidence of ARF of 2.8% and ARF-D of 1.7%. The highest risk group includes combined coronary artery bypass grafting/valvular surgery with an incidence of ARF of 4.6% and ARF-D of 3.3%.[10,11]

The most important thing with compensated renal failure patients during CPBG is to keep the perfusion time as short as possible to maintain the tissue circulation at optimum level. Because of this reason the flow rate must be calculated higher and peripheral vascular resistance must be measured quite often. Vasodilatation should be provided with pharmacological agents if necessary.[12] This brings forward the reason why the pump flow should be maintained as close to the calculated value as possible thus rising the importance of the venous return.

Gastrointestinal (GI) complications are infrequent (0.3% to 3%) but serious consequences of GI complications following cardiac surgery that includes cardiopulmonary bypass may ensue.[13] The mechanisms by which cardiopulmonary bypass can lead to GI complications have yet to be ascertained. Visceral vasoconstriction that occurs during bypass may contribute to this problem. In 1993, Ohri and coworkers demonstrated that transcellular transport in the small intestine was impaired and gut permeability was increased during cardiopulmonary bypass in 41 patients who had undergone cardiac operations. These findings coincided with mucosal hypoperfusion and ischemia that increased the likelihood of colonization and infection. The duration of cardiopulmonary bypass, congestive

heart failure, blood transfusions, re-exploration for bleeding and other factors were univariately associated with GI complications (such as use of inotropic support and Intraaortic balloon pump= IABP) and are often correlated with low cardiac output and systemic hypotension. Under such conditions, the likelihood of splanchnic hypoperfusion increases. The higher incidence of both triple-vessel disease and peripheral vascular disease in the GI group suggests that advanced arteriosclerotic disease increases the risk of visceral ischemia and, hence, the risk of GI complications.[14]

Neurological complications remain one of the most important problems despite of the improvements in surgical, anesthetical and perfusion techniques. The major complications like brain death, nonfatal stroke and transient ischemic attack occur as much as 3%, intellectual dysfunction, loss of concentration and memory may occur as high as 40-80%.[15,16] There are two kinds of cerebral damage after open heart surgery. One of them is hypoxic syndromes due to global cerebral hypoperfusion, the other one is ischemia-reperfusion damage secondary to embolism or inflammation.[17]

Intracardiac operations such as valve replacements typically carry a higher risk (4.2% to 13%) of overt central nervous system outcome, compared with coronary artery bypass grafting (CABG) procedures (0.6% to 5.2%).[18]

One of the risks of the low flow rate during CPBG is the thrombosis of arteriovenous fistulae via which the patients undergo hemodialysis.[19]

In our study, the pump flow rates of the patients undergoing CABG operations in the TS group patients had to be lowered to 3/4 and 1/2 of the normal during the distal anastomosis duration to the obtuse margin branches of the circumflex and posterior descending arteries of the right coronary arteries almost in all but one patient (Table 2) in comparison with the SS group patients where no pump flow changes were necessary during the distal anastomosis duration of the same areas (Table 3) ($p< 0.001$). The patients enrolled in this study had coronary arterial diseases with no accompanying illnesses that would inculcate unexpected morbidities postoperatively. Keeping in mind that regional venous desaturation due to potentially inadequate oxygen delivery, a component of which may be a reduction in the blood flow by a decrease in pump flow rate,[4] the presence of comorbid diseases would bring a high risk for postoperative aforementioned undesired clinical situations. This brings us to a point that every bit of measure should be taken into consideration in order to be able to maintain adequate oxygen supply to the tissues and this should start with the maintenance of the predetermined flow rates in an incessant manner.

CONCLUSION

Pump flow rate is the key to the success of the CPBG in terms of patient management peroperatively. Although some flow reductions may well be tolerated by the patients with isolated coronary artery diseases but otherwise healthy people, the ones having coexistent problems such as peripheral arterial disease, carotid artery disease and renal insufficiency may not be as lucky as others to compensate with the flow reductions during surgery under CPBG and may end up with undesired clinical outcomes. We therefore propose the use of the single stage cannulae at least especially in patients that will undergo an open heart surgery with coexistent problems in whom a reduction in flow rate during CPBG due to a possible decrease in the venous return is anticipated.

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