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REVIEW

Journal of Artificial Organs 2017: the year in review

Journal of Artificial Organs Editorial Committee

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Introduction

Members of the Editorial Committee of the Journal of Artificial Organs (JAO) are pleased to introduce to colleagues worldwide through the publication of JAO a broad spectrum of important new achievements in the field of artificial organs. We believe that JAO has a very high potential for promoting interest in the field of artificial organs. The impact factor announced in the Journal Citation Reports for 2016 was 1.350. We are proud of this impact factor, which will certainly enhance international interest in the journal.

From the beginning with volume 1 in 1998 to the last issue (volume 20) in 2017, we have received submissions from 21 countries, and we have accepted a total of 1078 papers for publication through the peer-review process. In volume 20, we published 64 articles, amounting to 403 pages in total, including 36 original articles, 2 review articles, 20 case reports, and 6 brief communications. These papers were related to the many aspects of basic research, development, and clinical application of artificial organs, covering a variety of subfields. The yearly acceptance rate was 59.6% in 2017. This review summarizes the content of some of the most intriguing papers of the last year.

During the last year, a total of 104 reviewers who were specialists in artificial organs and interdisciplinary fields helped our authors to improve their manuscripts through

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thoughtful reviews, critiques, and suggestions. We are very happy to present such excellent work in JAO. We would like to express our profound gratitude to all authors, reviewers, and members from all over the world, and express the hope that you will continue to support our journal.

Artificial heart (basic)

Date et al. [1] have developed a novel control system for a continuous-flow LVAD, and demonstrated that it could create sufficient pulsatility by changing rotational speed. In this study, they measured physiological parameters in acute animal experiments using six goats under shifting the timing of increase in the rotational speed of the EVAHEART from −60 to +60 mmHg, and they found significant increases in pulse pressure, mean dP/dt max of aortic pressure, and energy-equivalent pulse pressure in delayed timing of +60 ms. They are currently investigate the long-term effects of pulsatility for both normal hearts and hearts with chronic failure.

Nishida et al. [2] conducted the 2-year durability test of a newly developed axial-flow ventricular assist device (VAD) with hydrodynamic bearings. The test was carried out under pulsatile flow conditions with a mock circulation including a diaphragm pump to simulate LVAD circulation. Eight VADs were tested under almost constant conditions and they were driving successfully.

Shiba et al. [3] evaluated the internal electric field E and specific absorption rate (SAR) of human biological tissues surrounding an air-core coil transcutaneous energy transmission transformer. In their simulation, a primary coil was placed on the surface of the skin, and a secondary coil was located subcutaneously inside the body. The simulation was performed with electrical frequencies of 0.3–1.5 MHz and a transmitting power of 15 Ws. The results revealed that the E values were below the International Commission on Non-ionizing Radiation Protection (ICNIRP) limit for the general public exposure between the frequencies of 0.9 and 1.5 MHz, and SAR values were well below the limit prescribed by the ICNIRP for the general public exposure between the frequencies of 0.3 and 1.2 MHz.

Iizuka et al. [4] reported the influence of pump rotation speed on LVAD (EVAHEART) support with aortic valve regurgitation (AR). Hemodynamics and myocardial oxygen metabolism were examined in acute animal experiments using AR goat models which were placed a vena cava filter in the aortic valve. In the AR of Sellers classification 3 or greater, diastolic LVP was high and systolic LVP was hard to decrease, which indicated that increasing recirculation disturbed the unloading LV cardiac load with LVAD support. Oxygen extraction ratio was hard to decrease with increasing pump rotation speed and correlated with the flow rate of LVAD-LV recirculation ($p = 0.012$).

Mizuta et al. [5] demonstrated that the control time constant should be adjusted appropriately with the individual vasomotion frequency to improve the stability of the 1/*R* control. Data of five goats in which the undulation pump TAH had been implanted were analyzed with fast Fourier transform technique. The numerical simulation was conducted using the element-expanded Windkessel model and reproduced divergence and convergence of the 1/R control. These results suggested that the 1/*R* control tended to be unstable when the TAH recipient had high reflex speed in the baroreflex vascular system.

Matsuhashi et al. [6] investigated time-dependent thrombus formation at the interface between connectors and tubes. The sequential process of thrombus formation was observed using optical coherence tomography (OCT) with fresh human blood under pulsatile flow. Thrombus initially formed at the interface between the connector tip and the tube. Geometries of thrombus growth were different between the different connectors, and between the inlet and the outlet. Analysis using particle image velocimetry showed the presence of a flow reattachment point 1.5 mm downstream from the connector edge. These results suggest that the flow reattachment point inhibits downstream thrombus growth.

Artificial heart (clinical)

Imamura et al. [7] investigated the relationship between the frequency of driveline infection and specific features of drivelines. The driveline infections of 72 patients (32 with HeartMate II, 22 with EVAHEART, 18 with DuraHeart) were counted. HeartMate II group had the highest driveline infection-free rate among all three devices. The driveline of the HeartMate II had a significantly smaller outer diameter and lower stiffness than that of the other two devices. They concluded that the driveline features may affect the development of driveline infection.

Tibrewala et al. [8] examined the risks of left ventricular assist device (LVAD) implantation in patients taking an adenosine diphosphate receptor inhibitors (ADPRi). They demonstrated that the use of an ADPRi ≤ 5 days prior to LVAD implantation was not associated with increased bleeding, length of stay, or mortality in single-center experience.

Itoda et al. [9] reported a case with progressive aortic insufficiency (AI) during mechanical circulatory support with Jarvik 2000, for bridge to transplantation. Central aortic valve closure instead of valve replacement 20 months after Jarvik 2000 implantation was performed resulting in dramatic improvement of patient's symptoms.

Nakamura et al. [10] reported a case of gastric cancer in a patient bearing an implantable left ventricular assist device,

in which curative surgery was successfully performed. It is technically challenging to perform abdominal surgery in a patient with implantable left ventricular assist device. The innovative procedure by the authors would be extremely informative.

Seguchi et al. [11] retrospectively reviewed 23 Profile-1 patients who underwent ventricular assist device (VAD) implantation. They reported that VAD implantation for Profile-1 patients is an inevitable clinical issue at this time, while not only simple left VAD, but also right VAD and right VAD-ECMO were necessary for initial therapeutic strategies using VAD. They concluded that BiVAD-ECMO system is thought to be an effective therapeutic choice for Profile-1 patients with multiple-organ failure.

Yoshioka et al. [12] reported the case of a patient who developed warfarin resistance after LVAD implantation and developed a major stroke. The patient needed continuous intravenous heparinization until heart transplantation for approximately 2 years. This is the first case of warfarin resistance in a patient with LVAD.

Kunioka et al. [13] reported a rare case of acute myocardiao infarction, in which papillary muscle rupture occurred during left ventricular assist device support. In most of the cases, severe chronic MR was well tolerated after placement of left ventricular assist device, but it might not be the case with acute severe MR.

Kawabori et al. [14] reported the use of total artificial heart for fluminant eosinophilic myocarditis as a bridge to transplantation. In this case, total artificial heart was selected due to the following three reasons: (1) unresponsive to steroid therapy; (2) thick mural thrombi in the LV apex; (3) biventricular failure. Such a case might be rare, but total artificial heart could be a useful option.

Samura et al. [15] reported a case of salvage of a patient with non-occlusive mesenteric ischemia complicated with severe right ventricular dysfunction after left ventricular assist device implantation using maximum treatment with emergent laparotomy and temporary right ventricular assist device implantation.

Yamauchi et al. [16] reported the clinical results of patients with acute myocardial infarction (AMI) at the left main trunk (LMT) which treated with percutaneous cardiopulmonary support (PCPS). 10 of 27 (37%) patients were implanted LVAD, and 9 patients (33%) died. Their survival rates at 3 months and 1 year were 53.7 and 33.0%. They concluded that rapid cardiopulmonary resuscitation and coronary revascularization and timely insertion of LVAD before the onset of complications might lead to better survival.

Kimura et al. [17] investigated readmission after continuous flow left ventricular assist device implantation. The authors studied 90 patients who were discharged home after the device placement in their institute. During the mean follow-up of 713 days, 81% of the patients were re-admitted. The most common etiology was drive-line infection. The management of drive-line exit site is of extreme importance for long-term left ventricular assis device support.

Critsinelis et al. [18] reported the two cases with severe AI who underwent LVOT closure at the time of continuous-flow left ventricular assist device (CF-LVAD) implantation. Each of the two patients survived for more than 6 years without any complications related to LVOT closure. They concluded that surgical closure of the LVOT is a viable option for treating AI at the time of CFLVAD implantation.

Cardiopulmonary bypass

Kobayashi et al. [19] investigated the relationship between preoperative regional cerebral oxygen saturation and clinical variables during cardiac surgery, with regional cerebral oximetry using near-infrared spectroscopy device. They concluded that brain atrophy, poor left ventricular function, anemia, and hemodialysis were associated with low initial cerebral regional oxygen saturation values in adult cardiac surgery patients.

Jansen et al. [20] reported a case of a 45-year-old spina bifida patient with confirmed H1N1 influenza virus infection causing acute respiratory failure, who was successfully weaned from 42-day veno-venous extracorporeal membrane oxygenation (vv-ECMO) treatment with an excellent outcome. Due to the physical constitution of spina bifida patients, they experienced challenges concerning cannula positioning and mechanical ventilation settings during weaning.

Artificial lung/ECMO

Suga et al. [21] proposed a safe procedure of connecting renal replacement therapy device to an ECMO circuit by carrying out in vitro experiments to evaluate the safety of the circuit and demonstrated that hemofilter pressure remained in a safe range without jeopardizing the functions of the preceding ECMO circuit.

Scaravilli et al. [22] reported on a 38-year-old woman undergoing thyroidectomy complicated with sudden intraoperative bronchospasm by anaphylaxis due to atracurium, which leads to extreme hypercapnic respiratory failure, rescued by veno-venous ECMO. After extubation and disconnection from ECMO, the patient was discharged on the 6th day without sequelae. They concluded that rapid reversal of extreme hypercapnic acidosis by ECMO was feasible, without any neurologic sequelae, gaining the time for medical therapy to control the allergic reaction.

Hara et al. [23] have developed the sequential flow pump to make the ECMO system more compact and

potable. The sequential flow blood pump is unique because the position of the inlet and outlet port is the reverse configuration of conventional centrifugal blood pumps, and the sequential flow blood pump gives centrifugal force sequentially twice with a single closed impeller. They examined the performance of the sequential flow blood pump by CFD analysis and the in vitro experiment, and they showed the sequential flow blood pump has the possibility to realize the compact ECMO system.

Swol et al. [24] reported through a 32-year-old man with severe thoracic trauma complicated with pneumothorax and pneumopericardium repaired by bedside thoracotomy, followed by severe hypoxemia, required veno-venous ECMO thereafter. However, ultra-protective mechanical ventilation was not possible due to non-existent lung compliance; thus, the ventilator was disconnected, and the T-piece was connected to the blocked tracheal tube left in the airway. Gas exchange occurred via VV ECMO separately. After 48 h of cessation of ventilator support, the patient was back on assisted mechanical ventilation. The patient ultimately recovered with an excellent outcome. Although the clinical significance of zero end-expiratory pressure (ZEEP) and the complete cessation of open lung strategy during ECMO remains controversial, in cases of reduced lung compliance (VT less than 100 mL), discontinuation of ventilation is an option that can be used to prevent ventilator-induced lung damage and to allow the lungs to rest while on adequate VV ECMO support.

Kalbhem et al. [25] reported a repositioning maneuver of a dislocated Avalon Elite dual lumen catheter during ongoing veno-venous ECMO support. The inferior tip of the catheter dislocated into a liver vein, which was accompanied by a dramatic decrease in pump flow. After standard repositioning maneuvers under transthoracic echocardiographic guidance had failed, a special guiding sheath was inserted into the main lumen through a Y-connector with a valve. Over this valve, a stiff wire could be placed into the inferior vena cava to help guiding the catheter back into the correct position.

Lee et al. [26] reported on a difficult experience of veno-veno-arterial (VVA) ECMO in a patient with ARDS and septic-induced cardiomyopathy due to pulmonary tuberculosis. The patient was successfully managed using an appropriate alternative ECMO strategy.

Harnisch et al. [27] reported a case of case of a patient managed with three different ECLS devices sequentially, AV ECLA, VV ECMO, and ECCO2R, avoiding harmful effect of mechanical ventilation.

Cantwell et al. [28] reported a 39-year-old woman with leptospirosis-associated catastrophic respiratory failure complicated with pulmonary hemorrhage, which was successfully managed with ECMO.

Tissue engineering/regenerative medicine

Hirata et al. [29] reported the hepatocytic differentiation of iPSs on decellularized liver tissues (DLT) and decellularized heart tissues (DHT) to determine the tissue-specific effects of them on iPS differentiation. They found that DLTs led to higher gene expression levels of forkhead box A2, CCAAT/enhancer binding protein-α, α-fetoprotein, tyrosine aminotransferase and albumin of iPSs than on DHTs. Their study demonstrated that the use of DLTs led to mature hepatocytic differentiation levels of iPSs compared to DHTs, which provide a better niche for iPS cell engineering and enables the preparation of useful mature cells for regenerative therapy.

Artificial kidney/dialysis

Hashida et al. [30] analyzed the adsorbates on hemofilter used for acute kidney injury (AKI) patients with sepsis by comprehensive proteome analysis of the adsorbates. They found that adsorbates from the hemofilters of patients with sepsis had significantly increased frequency of proteins associated with "immune system process" and "biological adhesion" functions compared to those of non-sepsis patients. They also identified two proteins, carbonic anhydrase 1 and leucine-rich alpha-2-glycoprotein, as novel substances associated with sepsis.

Goto et al. [31] evaluated the adsorptive capacity of nafamostat masilate (NM) by a polyester polymer alloy (PEPA) membrane which has the property of adsorption. NM has been widely used as an anticoagulant during hemodialysis for patients with various hemorrhagic complications. NM adsorption was confirmed, especially in the early phase, and the PEPA membrane adsorbed greater amounts of NM than the polysulfone membranes.

Abe et al. [32] performed perfusion experiments that used non-machinery dialysis and recent blood purification machines in 30-min intervals.

They evaluated the effectiveness of non-machinery dialysis by assessing the removal efficiency of potassium. The non-machinery dialysis potassium removal rate was at the same level as continuous blood purification machines with a dialysate flow rate of 5 L/h after 15 min and continuous blood purification machines with a dialysate flow rate of 3 L/h after 30 min.

They concluded that non-machinery dialysis required an exclusive dialysate circuit, the frequent need to replace-bags, and new dialysate exchanged once every 30 min. However, it can be seen as an effective renal replacement-therapy for crush-related acute kidney injury patients, even

in locations or facilities not having the full-scale dialysis machines.

Maeda et al. [33] evaluated the interleukin-6 (IL-6) removal properties of mini-modules using polyester polymer alloy (PEPA) and cellulose triacetate (CTA) membrane. Plasma IL-6 was an important mediator of sepsis. Since IL-6 was not detected in the filtrate in PEPA group, it was considered that IL-6 was adsorbed to the membrane.

Apheresis

Chihara et al. [34] evaluated the effectiveness of induction timing of direct hemoperfusion with a polymyxin-B-immobilized column (PMX-DHP) for amelioration of hemodynamic derangement and outcome in patients with septic shock. They divided the patients into two groups that received PMXDHP therapy within 8 h (early group) and more than 8 h (late group) from catecholamine administration. They examined the changes in catecholamine dose [catecholamine index (CAI)], catecholamine dose/mean arterial pressure [catecholamine index pressure (CAIP)], PaO2/FiO2 and PEEP level at the start of and 24 h after the start of PMX-DHP therapy. They also examined ventilator-free days (VFD), ICU-free days (IFD), 28-day and hospital mortality. CAI and CAIP were significantly decreased in the early group. PEEP level in the early group was significantly decreased during PMXDHP therapy. Mortality at 28 days was significantly improved in the early group. They concluded that early induction of PMX-DHP therapy is recommended for the treatment of septic shock in patients with presumed Gram-negative infection.

Moriguchi et al. [35] demonstrated effectiveness and safety of plasma exchange in pediatric DCM patients. Plasma exchange was performed three times during 3 days in pediatric DCM patients both in acute and chronic phases and showed increased LVEF and decreased CTR and blood pressure, as well as no severe adverse effects.

Artificial liver and pancreas

Mita et al. [36] investigated the efficacy of a strict blood glucose control by an artificial endocrine pancreas during hepatectomy. They reported that the mean serum creatinine concentrations of preoperative, postoperative 24 and 48 h were 0.72, 0.78, and 0.79 mg/dL in the programmed insulin group, and 0.81, 0.95, and 1.03 mg/dL in the manual insulin group, respectively. They conclude that the strict blood glucose control using the artificial endocrine pancreas during hepatectomy may have potential effects to prevent postoperative acute kidney injury.

Artificial skin, muscle, bone/joint, and neuron

Large segmental long-bone defect remains as one of the most challenging conditions in orthopedic surgery. Honnami et al. [37] proposed a solution combining three recent technologies, tailor-made titanium mesh cage with fixating plate made by additive manufacturing, osteoconductive tetrapod-shaped calcium phosphate granules, and fibroblast growth factor-diffusing ion complex gel. They suggested that this combination would be a usuful solution for segmental bone defect.

Others

Alamusi et al. [38] reported the photoelectric dye-coupled polyethylene film, designated Okayama University type-retinal prosthesis or OURePTM, showed potential as retinal prosthesis using rat model. They implanted OURePTM subretinally in both eyes of ten Royal College of Surgeons rats with hereditary retinal dystrophy at the age of 6 weeks. Visual-evoked potentials in response to monocular flashing light stimuli were recorded. The amplitudes of visual-evoked potentials in the consecutive time points from 125 to 250 ms after flash were significantly larger in the seven eyes with dye-coupled film implantation at 8 weeks after the implantation.

Friesecke et al. [39] investigated the efficacy of a cytokine adsorption with CytoSorbTM in septic shock. They reported that following the initiation of adsorption therapy, noradrenaline dose could be significantly reduced after 6 (− 0.4 µg/kg/min; $p = 0.03$) and 12 h (− 0.6 µg/kg/min; $p = 0.001$) and that lactate clearance improved significantly. They conclude that the cytokine adsorption might be a rescue therapy option in patients with severe septic shock.

Fujita et al. [40] made a three-dimensional replica of the heart of the transplant patient who was diagnosed with congenitally corrected transposition of the great arteries (CCTGA). The 3D image data were obtained by the CT angiography and the three-dimensional replica was made of soft rubber using a 3D printer. The three-dimensional replica was helpful for heart transplantation, especially for CCTGA patients, because it can provide a more detailed understanding of the anatomy.

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