European Archives of Oto-Rhino-Laryngology (2019) 276:2747–2754
https://doi.org/10.1007/s00405-019-05524-3

OTOLOGY

Cochlear implantation after solid organ transplantation: long term results and review of the literature

Filippo Di Lella[1] · Ilaria Iaccarino[1] · Maurizio Negri[2] · Vincenzo Vincenti[1] · Federica Canzano[1] · Andrea Bacciu[1] · Enrico Pasanisi[1] · Maurizio Falcioni[1]

Received: 5 March 2019 / Accepted: 17 June 2019 / Published online: 21 June 2019

Abstract

Objective To analyze rate and type of complications in cochlear implant (CI) recipients receiving immunosuppressive therapy following solid organ transplant (SOT).

Study design Retrospective case series. English language literature review.

Setting Tertiary referral center.

Intervention Cochlear implantation surgery following solid organ transplantation (SOT) and immunosuppressive therapy.

Methods Data of patients who received CI after SOT and with at least one year of follow up were reviewed. Main outcome measures were the rate and type of complications, classified as major (requiring a second surgical procedure) and minor (requiring medical therapy). A search was performed in PubMed database on January 2019 using the keywords: *organ transplant; cochlear implant, complications, deafness, solid organ transplant, immunosuppressive therapy*. Only studies reporting on patients who have been implanted after the transplant procedure and with a follow up period of at least 1 year were considered. Final analysis was performed on pooled data.

Results Four patients received CI surgery following SOT. Age at treatment ranged from 40 to 47 years (mean 44.25 years). Follow-up after implantation averaged 5.25 years (range 1–10 years), without complications. Review of the available literature on the subject yielded seven papers; a total of 26 procedures in 22 patients satisfied inclusion criteria. Pooled data from the present series and from the literature were analyzed; the global rate of complications was 16.6%, with 10% major (3 of 30 procedures) and 6.6% minor (2 of 30 procedures). The three reported cases of major complications appear unrelated to SOT. Major complications were found in one case over 16 procedures in pediatric patients (6.2%), while in adults the percentage raised to 14.3% (2/14 procedures).

Conclusions Cochlear implantation is a safe and effective intervention, even during immunosuppressive therapy after organ transplantation.

Keywords Cochlear implantation · Organ transplantation · Postoperative complications

Introduction

Cochlear implantation (CI) is the standard of care for children and adult patients suffering from bilateral severe to profound hearing loss. The consistent results obtained with CI led to broadening of indications, including patients with inner ear and cochlear nerve malformations, otic capsule fractures, advanced age, ipsilateral vestibular schwannoma, chronic ear disease and systemic illness [1–4]. Patients who received solid organ transplants (SOT) present several challenges to the CI team as immunosuppressive therapy may predispose to poor wound healing and infections of the surgical site [5]. This study aims to evaluate the rate and type of postoperative complications in this particular population of implantees.

✉ Ilaria Iaccarino
ilariaiaccarino@gmail.com

[1] Otorhinolaryngology and Otoneurosurgery Department, University Hospital of Parma, Parma, Italy

[2] Otorhinolaryngology Department, Ramazzini Hospital, Carpi, Italy

Methods

All clinical investigations were conducted according to the principles expressed in the Declaration of Helsinki. Study protocol was submitted to the local ethical committee (1048/2018/OSS*/AOUPR, Prot. 47131); formal approval was not due as for case series. The otological surgical database of the Authors' tertiary referral university hospital was retrospectively reviewed. Medical charts, imaging and surgical reports of all patients who underwent cochlear implant surgery after solid organ transplantation from January 2007 to December 2018 were analyzed. Details regarding patient demographics, immunosuppressive therapy and transplant medical and surgical charts as well as functional results at last available follow up were collected in a retrospective manner. Antibiotic coverage, vaccination, surgical technique and type of anesthesia as well as functional audiological results at last available follow up visit were also collected. Patients were included if a CI was performed *after* the transplant procedure and had a follow up of *at least* 1 year.

A search was performed in PubMed database on January 2019 by the first Author using the following keywords: *organ transplant; cochlear implant, complications, deafness, solid organ transplant, immunosuppressive therapy*. Database was assessed by evaluating title, abstract, full text and checking for related articles in the references. From these articles only patients who have been implanted *after* the transplant procedure and with a follow up period of *at least* 1 year were included.

Final analysis was performed pooling data from the Literature and from the Authors' series.

Results

Over the study period, four patients (two males and two females) underwent organ transplantation and subsequent cochlear implantation at Authors' Institution. One of the patients received bilateral sequential CI; as follow up time of the second implant was shorter than 1 year (surgery performed in November 2018), the latter was not included in the study. Two more patients were implanted before the transplant procedure and were not included in the study. Two patients received kidney transplant (patients 1 and 2); they both had a history of progressive hearing loss, likely due to chronic renal failure and dialysis. Patients 3 and 4 were siblings affected by systemic amyloidosis and received liver and combined heart and liver transplant respectively. Additional surgery was performed once in patient 4 that required a second liver transplant and twice in patient 1 (two revision for kidney transplantation). Age at CI ranged from 40 to 47 years, with a mean of 44.25 years. The average time from SOT to CI was 4.25 years (range 3–6 years). All except patient 4 wore hearing aids before CI procedure. Preoperative clearance from the transplant team was obtained, immunosuppressive therapy continued preoperatively in all patients and immunosuppression levels regularly checked. Preoperative immunization with 23-valent pneumococcal polysaccharide vaccine (PPV23) was administered prior to CI to each patient. Intravenous ceftazidime was administered preoperatively and all patients continued the same antibiotic for 7 days after surgery. All procedures were performed through a standard transmastoid facial recess approach with complete electrode insertion; two of the patients (patients 1 and 4) underwent surgery under local anesthesia due to anaesthesiological contraindications. Surgery and immediate postoperative period were uneventful in all cases. Follow up ranged from 18 months to 10 years, with a mean of 5.25 years; none of the patients was lost to follow up. None of the patients experienced complications and all patient reached open set abilities. Patient 3 died 6 years after cochlear implant.

Literature review yielded seven papers [5–9, 20, 25]. Due to short follow up period (< 1 year), papers from Hashemi et al. [6] and Mahalingham et al. [7] were not included. For the same reason a total of three patients had been excluded from other papers: two from the Suhling [8] and one from the Ayub and Young series [9]. Three additional patients were excluded because CI surgery was performed before SOT procedure, two from the Suhling paper [8] and the other from the Patterson et al. series [5]. A total of 26 procedures in 22 patients were thus considered eligible for final analysis.

Global analysis was performed pooling data from the Literature and from the Authors' present series; details are summarized in Table 1.

Total number of procedures was 30 CIs on 26 patients. Mean age at first CI was 28 years (range 2.2–73 years); pediatric patients were 12, with a mean age at first CI of 5 years (range 2.2–11.7 years). Adults were 14 with a mean age at first CI of 47.7 years (range 18.6–73 years). Mean time interval between SOT and first CI procedures was 3.7 years (range 0.5–10.3 years). One pediatric patient underwent simultaneous bilateral implantation in Ayub et al. series, while three more children from Suhling et al. underwent sequential bilateral CI. Mean follow up after first CI was 4.3 years (range 1–13.1 years). Follow up data were available for first CI in 24 patients as two patients from the Suhling series underwent follow up in another center. Total number of complications was 5 over 30 procedures (16.6%), with three major (10%) and two minor (6.6%) complications. Of the three cases of major complications, two were hard device failure, occurring after 4.6 and 10 years from the

Table 1 Clinical data including patients from Literature review and Author's present series

Author (year)	Subject	Type of SOT	Age at CI (years)	Timing of CI after SOT (years)	Vaccine	Antibiotic regimen	Preoperative steroids	Complications	Follow up (years)
Patterson et al. (2007) [5]	1	Kidney	73	4.2	One dose of PPV23	Preoperative levofloxacin 500 mg iv + non specified post operative	Single dose dexamethasone IV 8/12 mg	None	2.7
	2	Heart	71	8.2	One dose of PPV23	Preoperative cefazolin 1 g IV + non specified post operative	Single dose dexamethasone IV 8/12 mg	Major hard device failure	4.6
	2b reimplantation					NS			2.1
	3	Liver/kidney	43	0.5	One dose of PPV23	Preoperative cefazolin 1 g IV + non specified post operative	Single dose dexamethasone IV 8/12 mg	None	1.4
	4	Kidney	26	1	One dose of PPV23	Preoperative cefazolin 1 g IV + non specified post operative	Single dose hydrocortisone IV 100 mg	Major hard device failure	10.1
	4b reimplantation					NS			1.6
Cortina et al. (2009) [25]	1	Kidney	4	1.6	NS	Postoperative amoxicilline and clavulanic acid for 1 wk	NO	None	2
Iverson and Mc Kinnon (2012) [20]	1	Kidney	53	6.3	NS	Preoperative cefazolin 1 g IV + postoperative cephalexin for 1 wk	NO	None	1.1
	2	Kidney	53	0.6	NS	Preoperative cefazolin 1 g IV + postoperative cephalexin for 1 wk	NO	None	1.6
Ayub and Young [9]	1	Heart	7.2	7	PCV7, PCV13, PPV23, HiB	NS	NO	None	1
	2	Lung	4.9	4	PCV7, PPV23, HiB	NS	NO	None	5

Table 1 (continued)

Author (year)	Subject	Type of SOT	Age at CI (years)	Timing of CI after SOT (years)	Vaccine	Antibiotic regimen	Preoperative steroids	Complications	Follow up (years)
	3	Lung	18.6	1.1	PPV23	NS	NO	None	4.4
	4	Liver	4.4	4	PCV7,PPV23,HiB	NS	NO	None	1.5
	5	Heart	2.4	2	PCV7, PCV13, PPV23, HiB	NS	NO	None	2
	5a simultaneous								
	6	Liver/kidney	18.7	8.7	PPV23,HiB	NS	NO	None	13.1
Suhling et al. (2018) [8]	1	Liver	2.8	2.2	NS	Co-amoxiclav (duration not specified)	NO	None	NS (other center)
	2	Liver	2.2	1.8	NS	Co-amoxiclav (duration not specified)	NO	None	6.8
	2a sequential		4.5	4.1	NS	Co-amoxiclav (duration not specified)	NO	Major epitympanic cholesteatoma (1 year after 2nd CI)	NS
	3	Liver	11.7	0.8	NS	Co-amoxiclav (duration not specified)	NO	Minor exanthema on the head (4.7 years after CI)	3.9
	4	Liver	3.3	1.4	NS	Co-amoxiclav (duration not specified)	NO	None	9.8
	4a sequential		7.6	5.7	NS	Co-amoxiclav (duration not specified)	NO	None	NS
	5	Kidney	4.2	1.1	NS	Co-amoxiclav (duration not specified)	NO	None	NS (other center)
	6	Kidney	71.3	9.1	NS	Co-amoxiclav (duration not specified)	NO	None	2.2
	7	Kidney	2.5	1.6	NS	Co-amoxiclav (duration not specified)	NO	None	6.8
	7a sequential		14.9	14	NS	Co-amoxiclav (duration not specified)	NO	None	NS

Table 1 (continued)

Author (year)	Subject	Type of SOT	Age at CI (years)	Timing of CI after SOT (years)	Vaccine	Antibiotic regimen	Preoperative steroids	Complications	Follow up (years)
	8	Lung	10.9	1.3	NS	Co-amoxiclav (duration not specified)	NO	Minor wound-healing disorder (early postoperative)	1.9
	9	Lung	63.2	10.3	NS	Co-amoxiclav (duration not specified)	NO	None	1.1
Present series	1	Kidney (three times)	46	3	One dose of PPV23	Preoperative + postoperative ceftazidime 1 g IV for 1 wk	NO	None	4
	2	Kidney	44	5	One dose of PPV23	Preoperative + postoperative ceftazidime 1 g IV for 1 wk	NO	None	10
	3	Liver	40	6	One dose of PPV23	Preoperative + postoperative ceftazidime 1 g IV for 1 wk	NO	None	6
	4	Liver (twice), heart	47	3	One dose of PPV23	Preoperative + postoperative ceftazidime 1 g IV for 1 wk	NO	None	1
	Total number of patients: 26 Total number of CIs: 30		Mean: 28 Pediatric: 5 Adult: 47.7	Mean: 3.7				Total number of complications: 5/30 CIs (16.6%) Minor: 2(6.6%) Major: 3 (10%)	Mean: 4.3

CI cochlear implant, *IV* intravenous, *NS* not specified, *SOT* solid organ transplant, *wk* week

CI procedure [5] and the third was an epitympanic cholesteatoma 1 year after the second CI [8]. Skin problems have been reported as minor and temporary complications in two patients and were treated medically [8].

Discussion

One of the most feared complications in CI surgery is represented by infection and extrusion of the device, although antibiotic coverage, rigorous asepsis and meticulous surgical procedures keep the incidence to a minimum [10–14]. Solid organ transplantation patients require life-long immunosuppressive therapy to reduce/prevent graft rejection and present an increased risk of infection of the surgical site, with potentially severe complications [15]. To date only isolated reports and few case series addressed the complications rate after cochlear implantation in this particular population of implantees.

Susceptibility of SOT patients to postoperative complications after prosthetic implantation procedures, i.e. joint replacement surgery, is a well known problem: Tannenbaum et al. found a 19% infection rate among organ recipients after joint replacement against a global 1.2% rate for all joint replacement procedures performed at their institute during the same period [16]. In 2014, Ledford et al. evaluated complications and functional results in total hip (THA) and total knee arthroplasty (TKA) in transplants recipients. They experienced a high rate of overall perioperative medical complications (29% and 33%, respectively), a high need for reintervention due to noninfectious causes (7.2% and 9.1%) and periprosthetic infection in 1.8% of the THA group and 14.2% in TKA group. Despite these, both groups had significant improvement in functional scores and self reported patients outcomes [17]. In 2016 the same Authors reported as SOT patients with TKA had a higher rate of perioperative complications than TKA in general population [18].

In the CI procedure, potential complications include device failure, infection of the surgical wound, healing problems associated with the soft tissue coverage over the receiver stimulator, device extrusion, mastoiditis, and meningitis [7]. Several issues should then be addressed when considering a SOT patient for a surgical procedure and particularly for a cochlear implantation to reduce additional risks to a minimum [9].

As stated by Patterson et al. [5], appropriate timing of CI after transplant is an important consideration in predicting infection risk. Rubin et al. described the expected sequence of infection type after organ transplantation: for the first month after transplant, the patient is at risk for conventional nosocomial infections; between 1 and 6 months, there is increased risk for opportunistic infection while after 6 months post-transplantation, peak immunosuppression has passed and most infections are community-acquired [19]; it may be advisable to consider CI not before a minimum of 6 months after transplantation in order to wait the peak of immunosuppressive effect to subside [20]. Perioperative pharmacological therapy is another relevant issue; transplant team should be consulted and immunosuppressive therapy level should be monitored. Administration of steroids associated with the usual therapy has been reported as useful in order to reduce the stress response of surgery [5]. The microbiology team should also be consulted in regards to vaccination and antibiotics. According to American Society of Transplantation [21, 22] all organ recipients over the age of 5 years should receive at least one 23-valent pneumococcal polysaccharide vaccine (PPV23) before transplant procedure. The CDC vaccination schedule initially included PCV7 for implanted children under age 5 years and PPV23 for children above 2 years and adults [23]. These guidelines have been updated to include PCV13, which replaced PCV7 in 2010. PCV13 is furthermore recommended for CI candidates and recipients of all ages [24].

No guidelines exist about antibiotic therapy in SOT patients undergoing cochlear implantation.

From the available literature a total of 26 CI procedures in 22 SOT patients were considered from previous reports on the topic; patient who received CI *before* SOT and patient with short (i.e. < 1 year) follow up were not considered in the analysis for obvious reasons. Various schemes of antimicrobial regimens, vaccine schedule and preoperative steroids are reported and available in Table 1. Patterson et al. [5] described a series of five patients; one of them had cochlear implantation before trasplantation and was thus excluded from this review. Two had renal transplantation, one combined kidney–liver transplantation and one heart transplantation. No immediate postoperative complications were described; device hard-failure was reported in two patients that required revision surgery after 4.6 and 10 years, respectively. One of the four patients had poor audiological results. Cortina et al. described a 4-year-old boy with congenital renal dysplasia who underwent CI surgery 2 years after kidney transplantation. He had no complications and good audiological results [25]. Iverson and McKinnon [20] described two renal transplant recipients who after CI experienced a regular postoperative period with no complications and good audiological outcomes. Ayub and Young [9] described seven different solid organ transplantations: the four males and three females ranged in age at CI from 2.4 to 18.8 years, with a mean of 9.0 years. Follow-up averaged 3.9 years. There were no postoperative complications. Four patients developed open-set speech perception used only oral communication; one child used primarily sign communication with some oral communication; one was an inconsistent device user and did not develop speech perception or oral language

with consequent cognitive deficits; follow-up was less than 1 year for one patient that was excluded from our analysis. Finally, Suhling et al. [8] recently described 13 patients and 17 cochlear implants. The first implantation took place at ages ranging from 2.2 to 71.3 years (mean 11.2 years). The overall reported complication rate was 29.4% (5/17), with major and minor complications occurring both in three cases (17.6%). None of adult patients developed complications. The Authors claimed a higher rate of complications rate than that reported in the Literature, but it is to note that three of the 5 reported complications presented in two patients who received CI more than 10 years *before* SOT and were consequently not considered in this analysis; another two patients with inconsistent follow up (< 1 year) but without complications were also removed.

When pooling data from Literature patients that satisfy inclusion criteria and the Authors' present series, a total of 30 procedures in 26 patients have been performed, with 3 major (10%) and 2 minor (6.6%) complications, for a global rate of 16.6%. With the obvious limits of this analysis (small number of patients, retrospective case series and literature review), it appears that complication rate almost equals that of global reports of referral European Centers of 19.9% (with 5% major) [26], 13.8% (with 3.4% major) [8] and 18.3% (with 2.3% major) [27].

It is interesting to note that the three cases of major complications appear unrelated to the SOT, with an epytimpanic cholesteatoma of possible iatrogenic origin in one case [8] and hard device failure in two other patients [5].

Conclusions

Cochlear implantation can be considered a safe and effective procedure in immunocompromised patients following solid organ transplant, even in the pediatric age. Rigorous asepsis, antibiotic coverage and targeted vaccination schedules should be routinely applied.

Funding None.

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

Ethical statement All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animals are involved.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Vincenti V, Pasanisi E, Bacciu A, Bacciu S, Zini C (2014) Cochlear implantation in chronic otitis media and previous middle ear surgery: 20 years of experience. Acta Otorhinolaryngol Ital 34(4):272–277
2. Vincenti V, Ormitti F, Ventura E, Guida M, Piccinini A, Pasanisi E (2014) Cochlear implantation in children with cochlear nerve deficiency. Int J Pediatr Otorhinolaryngol 78(6):912–917
3. Bacciu A, Pasanisi E, Vincenti V et al (2009) Cochlear implantation in children with cerebral palsy. A preliminary report. Int J Pediatr Otorhinolaryngol 73(5):717–721
4. Vincenti V, Pasanisi E, Guida M, Di Trapani G, Sanna M (2008) Hearing rehabilitation in neurofibromatosis type 2 patients: cochlear versus auditory brainstem implantation. Audiol Neurootol 13(4):273–280
5. Patterson DM, Telischi FF, Connell SS et al (2007) Cochlear implantation in organ transplantation. Laryngoscope 118(1):116–119
6. Hashemi SB, Bahrani Fard H, Zandifar Z (2012) Cochlear implantation after kidney transplantation. Int J Org Transpl Med 3:130–131
7. Mahalingam S, Rajeev M, Sharmila P et al (2014) Cochlear implantation in a patient with combined renal and liver transplantation. Cochlear Implants Int 15(6):333–336
8. Suhling MC, Lenarz T, Teschner M (2018) Cochlear implants in organ transplant recipients. Otol Neurotol 39:e774–e783
9. Ayub B, Young NM (2016) Cochlear implantation of solid organ transplant patients receiving immunosuppressive therapy. Int J Pediatr Otorhinolaryngol 91:19–22
10. Hopfenspirger MT, Levine SC, Rimell FL (2007) Infectous complications in pediatric cochlear implants. Laryngoscope 117:1825–1829
11. Cunningham CD III, Slattery WH III, Luxford WM (2004) Postoperative infection in cochlear implan patients. Otolaryngol Head Neck Surg 131:109–114
12. McJunkin J, Jeyakumar A (2010) Complications in pediatric cochlear implants. Am J Otolaryngol Head Neck Med Surg 31:110–113
13. Hansen S, Anthonsen K, Stangerup SE et al (2010) Unexpected findings and surgical complications in 5050 consecutive cochlear implantations: a proposal for reporting consensus. Acta Otolaryngol 130:540–549
14. Loundon N, Blanchard M, Roger G et al (2010) Medical and surgical complications in pediatric cochlear implantation. Arch Otolaryngol Head Neck Surg 136:12–15
15. Flechner SM, Zhou L, Derweesh I et al (2003) The impact of sirolimus, mycophenolate mofetil, cyclosporine, asathioprine, and steroids on wound healing in 513 kidney-transplant recipients. Transplantation 76:1729–1734
16. Tannenbaum DA, Matthews LS, Grady-Benson JC (1997) Infection around joint replacement in patients who have a renal or liver transplantation. J Bone Joint Surg Am 79:36–43
17. Ledford CK, Watters TS, Wellman SS et al (2014) Risk versus reward: total joint arthroplasty outcomes after various solid organ transplantations. J Arthroplast 29:1548–1552
18. Ledford CK, Chalmers BD, Statz JM et al (2017) Primary total knee arthroplasty after solid organ transplant: survivorship and complications. J Arthroplast 32:101–105
19. Rubin RH, Wolfson JS, Cosimi AB, Tolkoff-Rubin NE (1981) Infection in the renal transplant recipient. Am J Med 70:405
20. Iverson KC, McKinnon BJ (2012) Cochlear implantation after renal transplantation. Am J Otolaryngol 33:150–153

21. Danzinger-Isakov L, Kumar D (2009) Guidelines for vaccination of solid organ transplant candidates ad recipients. Am J Transpl 9(Suppl 4):S258–S262
22. Danzinger-Isakov L, Kumar D (2013) Vaccination in solid organ transplantation. Am J Transpl 13:311–317
23. Center for Disease Control and Prevention (2003) Pneumococcal vaccination for cochlear implant candidates and recipients: updated recommendations of the advisory committee on immunization practicers. Morb Mortal Wkly Rep 52:739–740
24. Centers for Disease control and Prevention (2016) Use of vaccines to prevent meningitis in persons with cochlear implants. https://www.cdc.gov/vaccines/vpd-vac/mening/cochlear/dis-cochlear-gen.htm. Accessed 15 June 2016
25. Cortina G, Wiesmayr T, Jungraithmayr D et al (2009) Successful implantation of a cochlear implant in a 4-year-old boy after kidney transplantation: a case report. Pediatr Transpl 13:933–935
26. Farinetti A, Ben Gharbia D, Mancini J, Roman S, Nicollas R, Triglia JM (2014) Cochlear implant complications in 403 patients: comparative study of adults and children and review of the literature. Eur Ann Otorhinolaryngol Head Neck Dis 131(3):177–182
27. Bhatia K, Gibbin KP, Nikolopoulos TP, O'Donoghue GM (2004) Surgical complications and their management in a series of 300 consecutive pediatric cochlear implantations. Otol Neurotol 25(5):730–739