Aging Clin Exp Res (2017) 29 (Suppl 1):S55–S63
DOI 10.1007/s40520-016-0676-5

ORIGINAL ARTICLE

Robot-assisted surgery in elderly and very elderly population: our experience in oncologic and general surgery with literature review

Graziano Ceccarelli[1] · Enrico Andolfi[1] · Alessia Biancafarina[1] · Aldo Rocca[1,2] · Maurizio Amato[3] · Marco Milone[3] · Marta Scricciolo[1] · Barbara Frezza[1] · Egidio Miranda[1] · Marco De Prizio[1] · Andrea Fontani[1]

Received: 4 September 2016 / Accepted: 3 November 2016 / Published online: 30 November 2016

Abstract
Background Although there is no agreement on a definition of elderly, commonly an age cutoff of ≥65 or 75 years is used. Nowadays most of malignancies requiring surgical treatment are diagnosed in old population. Comorbidities and frailty represent well-known problems during and after surgery in elderly patients. Minimally invasive surgery offers earlier postoperative mobilization, less blood loss, lower morbidity as well as reduction in hospital stay and as such represents an interesting and validated option for elderly population. Robot-assisted surgery is a recent improvement of conventional minimally invasive surgery.
Aims We provided a complete review of old and very old patients undergoing robot-assisted surgery for oncologic and general surgery interventions.
Patients and methods A retrospective review of all patients undergoing robot-assisted surgery in our General Surgery Unit from September 2012 to June 2016 was conducted. Analysis was performed for the entire cohort and in particular for three of the most performed surgeries (gastric resections, right colectomy, and liver resections) classifying patients into three age groups: ≤64, 65–79, and ≥80. Data from these three different age groups were compared and examined in respect of different outcomes: ASA score, comorbidities, oncologic outcomes, conversion rate, estimated blood loss, hospital stay, geriatric events, mortality, etc.
Results Using our in-patient robotic surgery database, we retrospectively examined 363 patients, who underwent robot-assisted surgery for different diseases (402 different robotic procedures): colorectal surgery, upper GI, HPB, etc.; the oncologic procedures were 81%. Male were 56%. The mean age was 65.63 years (18–89). Patients aged ≥65 years represented 61% and ≥80 years 13%. Overall conversion rate was of 6%, most in the group 65–79 years (59% of all conversions). The more frequent diseases treated were colorectal surgery 43%, followed by hepato-bilopancreatic surgery 23.4%, upper gastro-intestinal 23.2%, and others 10.4%.
Discussion Robot-assisted surgery is a safe and effective technique in aging patient population too. There was no increased risk of death or morbidity compared to younger patients in the three groups examined. A higher conversion rate was observed in our experience for patients aged 65–79. Prolonged operative time and in any cases steep positions (Trendelenburg) have not represented a problem for the majority of patients.
Conclusions In any case, considering the high direct costs, minimally invasive robot-assisted surgery should be performed on a case-by-case basis, tailored to each patient with their specific histories and comorbidities.

Keywords Robotic surgery · Minimal invasive surgery · Cancer · Elderly · Geriatric · Aging population

✉ Aldo Rocca
aldorocca@hotmail.it

[1] Department of Surgery, Division of General Surgery, Hospital of Arezzo, Arezzo, Italy

[2] Department of Clinical Medicine and Surgery, University of Naples "Federico II", Via Sergio Pansini, 80131 Naples, Italy

[3] Department of Surgical Specialities and Nephrology, University of Naples "Federico II", Naples, Italy

Introduction

An aging population continues to rise with remarkable implications for every national healthcare system, especially in Western countries, increasing the burden of resources for care.

Elderly population and in particular octogenarians are steeply increasing; in 2009, the percentage of the UK population aged 65 years and over was 16%; it is expected that by 2034, this population will rise to 23% [1, 2]. Over the past 20 years, the population older than 85 years quadrupled leading to a nearly 50% increase in the annual cancer incidence.

With this trend, cancer will become a disease of the elderly [2–5]; but in this aged population, cancer often occurs as an advanced stage of the disease. Therefore, a close collaboration between surgical associations and geriatric societies is necessary to produce guidelines for the perioperative assessment and management of postoperative geriatric events [6–8].

Elderly patients compared to younger ones frequently have one or more comorbidities and are often "frail"; they are at greater risk of morbidity and mortality. Optimizing a care pathway during the perioperative period, in particular anesthesiologic best practice, promoting and improving enhanced recovery programs, may be fundamental.

Frailty is a state of vulnerability that carries an increased risk of poor outcomes in elderly people. Common signs and symptoms are feeling of fatigue, weight loss, muscle loss and weakness, slow walking speed, low levels of physical activity, and progressive decline in body function. Frail people are at higher risk of falls and have a much longer time for recovering if they become ill or have undergone surgery. Frail older people are less able to tolerate the stress of medical illness, hospitalization, and immobility; consequently, surgery may be a substantial problem in this population. About 4% of men and 7% of women older than 65 were frail. However, it must be pointed out that some old people do not get frail. Some medications may worsen frailty with their side effects [9].

Recent data show the feasibility of surgical treatment in elderly in several types of cancers, such as sarcomas [10, 11], gynecologic cancer [12], urologic cancer [13], colorectal cancer [14, 15], or pulmonary surgery [16]; otherwise, complication rates, mortality, length of hospital stay, and intensive care unit admissions increase with patient age [17].

A lot of cancers with or without genetic pathogenesis and expressing several specific markers [18–22] can be also useful treated using novel therapeutic approaches like cell-based therapy or targeting therapies [23–32]. Nevertheless, these new approaches can be still used in non-oncologic diseases in aging patients [33, 34].

In this sense, minimally invasive surgery (MIS) has been shown to be better tolerated than open surgery, in selected elderly population [35]. MIS is often associated with shorter hospital stays, less postoperative pain, faster recovery, faster mobilization, better respiratory function recovery, reduced morbidity, and no difference in oncologic outcomes as compared to open surgery [13, 14, 36, 37].

Robot-assisted surgery, representing a technological evolution of laparoscopy and thoracoscopy, started only a few years ago [38, 39]. It allows more patients to benefit from MIS, overcoming many laparoscopic drawbacks and limitations. It is used and widely accepted in general surgery and in particular in oncologic surgery [40–45]. Some concerns are recognized in the use of robotic in the elderly population, especially when considering a longer operative time as reported by several studies; furthermore, some procedures require prolonged and steep Trendelenburg position (e.g., rectal and prostatic surgery), with possible consequences about pulmonary and cardiovascular implications [46, 47].

This is a retrospective analysis of our personal experience in robotic-assisted general surgery, focused on elective oncologic, colorectal, upper GI, and HPB surgery integrated with a literature review. We attempt to better define the use of this new technological approach in elderly people, especially octogenarian, analyzing the potential benefits, limits, and risks.

Patients and methods

A review of 363 consecutive patients undergoing robotic-assisted surgery (RAS) from September 2012 to June 2016 was conducted. All patients regardless of age, gender, type of surgical procedure, and conversion rate were included in the study. We focused on the older population, comprising ages of $\geq$65 and >80 years.

In particular, the patients of three different procedures (right colectomy, gastric resection, and liver resections) were divided into three groups based on age brackets, namely: group 1, $\leq$65 years old; group 2, 50–79 years old, and group 3, $\geq$80 years old. Outcomes of the three groups were examined in respect of ASA score, comorbidities, tumor characteristics, operative details, and postoperative outcomes, then compared and analyzed.

The primary objective was to analyze the whole robotic group in respect of gender, age, conversion rate, causes of conversion, and type of surgical procedures performed. Than for the three different surgical procedures, the median operating time, estimated blood loss, length of hospitalization, Clavien–Dindo complication rate, and mortality were compared respect age cohort.

To assess the potential impact of geriatric events, we examined several additional outcomes: inpatient comorbidities; length of stay; intraoperative estimated blood loss (EBL); postoperative infection; pulmonary failure; sepsis; venous thromboembolism; and wound complications.

Results

From September 2012 to June 2016, we treated 363 patients who underwent minimally invasive robot-assisted surgery (RAS) for different diseases in our surgical unit (402 different robotic procedures): colorectal surgery, upper GI, HPB, etc. The oncologic procedures were 81%, with male patients representing 56%. The mean age was 65.63 years (18–89). The youngest was an 18-year-old female affected by a giant splenic hemangioma, who underwent a robot-assisted hemi-splenectomy. The oldest was an 89-year-old man affected by hepatocarcinoma of the 6th segment of liver who had a robot-assisted hepatic resection.

The patient group aged ≥65 years represented 61% and that ≥80 years 13%. Overall conversion rate was of 6%, most of them in the group 65–79 years old (59% of all conversion rate); the most frequent causes for conversion were: locally advanced tumors and intraoperative bleedings. The more frequent diseases treated were colorectal surgery 43%, followed by hepatobilopancreatic surgery 23.4% and upper gastro-intestinal surgery 23.2%, others 10.4% (Table 1; Fig. 1).

Table 1 Diseases treated using robot-assisted surgery (from September 2012 to June 2016

Right hemicolectomy	66
Left hemicolectomy + transverse	47
Rectal resection	56
Total colectomy	1
Reverse Hartmann	2
Gastric resection	60
Fundoplicatio	23
Heller myotomy	10
Liver resection	51
Pancreatic surgery	11
Cholecystectomy	32
Splenectomy	11
Adrenalectomy	10
Partial nephrectomy	3
Paraortic lymphnode harvesting	8
Others (hernia/incisiona h/hister, etc)	11
Total robotic procedures	402

Neoplasms were the predominant disease which affected about 81% of the patients; others were functional and benign diseases (e.g., gastroesophageal disease, achalasia, diverticular diseases, benign splenic diseases).

The patients of the three major diseases were compared between the three age groups with respect to ASA score, comorbidities, disease stage, EBL, Clavien–Dindo complications, operative time, recovery time, hospital stay (Tables 2, 3, 4).

The rate of overall complication and conversion rate was higher in the 65–79 and >80 groups. This may be easily justified by the major incidence of high-stage disease, higher ASA score, and higher comorbidities observed in the two oldest groups.

In the gastric resection group, the mean hospital stay did not differ among the younger <65 and older >80 (8.2 vs 8.9) groups, while a higher hospital stay in the 65–79 group was due to a higher complication rate. Regarding the oncologic outcomes referring to nodes harvesting, we observe a reduction in mean rate from 28 in the <65 group to 19 in >80 group (Table 2).

Observing the liver resection (Table 3), the three age groups were inconsistent in sample size, but the disease characteristics were similar (cirrhotic liver, percentage of benign diseases treated, associated surgery performed), the prevalence of posterior segments treated was higher in the population of less than 80 years old. With respect to gastric resection group, the conversion rate was without great difference but complication rate Clavien–Dindo I–II was higher in the group >80 years, with only a reoperation for biliary leakage in the group 65–79 years. There was no significative difference in positive margins at histologic examination. In the right colectomy cohort (Table 4), though the small sample of the >80-year-old patients, despite an higher conversion rate in the older two groups due to locally advanced disease, we observed similar mean operative time and hospital stay. Only one 30-day readmission was observed in the youngest age group.

Discussion

The population of Western countries continues to grow older. The cutoff for a definition of elderly patients vary from 65 and 70 years of age [48–50]. Defining elderly patients based on functional status is more accurate than the actual age.

Aging, especially if associated with cancer, is commonly related with a functional decline, cognitive disorders, frailty, comorbidities, malnutrition, falls, and polypharmacy, resulting in a greater vulnerability and institutionalization as well as rising in health system costs. Oncologic patients often are not able to bear neoadjuvant

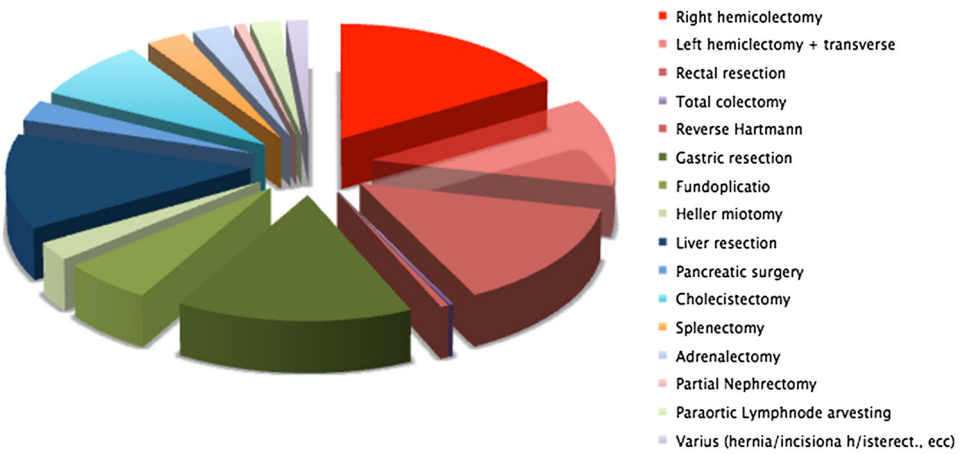

Fig. 1 Groups of diseases treated by robotic approach

Table 2 Robot-assisted gastric resections cohort

Robot-assisted gastric resections (2012/1-6-2016)			
	<65	65–79	>80
N patients[b]	19 (30%)	33 (52%)	11 (17%)
ASA I–II (%)	17 (89%)	16 (48%)	1 (9%)
ASA III–IV (%)	2 (11%)	17 (52%)	10 (91%)
No comorbidity (%)	12 (63%)	7 (21%)	0%
1–2 comorbidities (%)	5 (26%)	16 (49%	4 (36%)
3 or >comorbid. (%)	2 (11%)	10 (30%)	7 (64%)
Wedge/subt gastrect	14	27	8
Total gastrectomy	5	6	3
Associated procedures	4	15	4
Lymphnode harvest.[a]	28.46 (18–55)	23.76 (12–45)	19.8 (828)
Lymphnodes+/M+	4	13	2
*T*1–*T*2	14	22	6
*T*3–*T*4	5	11	5
Mean oral intake	4.3	4.8	4.9
Mean hospital stay	8.21 (5–17)	13.25 (5–90)	8.9 (5–13)
Clavien–Dindo I–II	4	9	6
Clavien–Dindo III–IV[b]	0	1	0
30-day deaths	0	0	0
Conversion rate (%)	2 (10.5%)	4 (12%)	2 (18%)
EBL < 50	13	18	5
EBL 50–100	5	8	4
EBL > 100	1	7	2
Mean operative time	262′ (120–440)	284′ (150–480)	259′ (110–455)

[a] Only for adenoca

[b] Reoperation

or adjuvant chemotherapy due to cardiac diseases, renal failure, toxicity, or intolerance/side effects during cancer treatment [4, 51–53].

Age represents an independent risk factor for morbidity and mortality, and when associated with surgical procedures, it will lead to unacceptably high risks of postoperative morbidity rate [54, 55]. Nowadays it is not justified denying elderly patients surgical procedures only on the basis of age. It was demonstrated that elderly patients who survive the first year after surgery have the same cancer-related survival as younger patients [56].

Frailty is defined by medical geriatrics as a syndrome of decreased physiologic reserve that limits a patient's ability to respond to stress and predisposes patients to adverse

Table 3 Robot-assisted liver resection cohort

Robot-assisted liver resection (2012/1-6-2016)			
	<65	65–79	>80
N patients[b]	16 (33%)	24 (49%)	9 (18%)
Post-segments VII–VIII + II (%)	43%	50%	22%
Cirrhosis (*n*)[b]	4	3	1
Benign Dis. (%)	18%	29%	22%
Associated surgery (%)	50%	45%	44%
Mean oper. time	251′ (65–310)	179′ (65–245)	233′ (170–320)
Conversions rate (%)	2 (12.5%)	2 (8.3%)	1 (11%)
Mean diamet. lesion(mm)	3.2 (1.5–5.5)	2.2 (0.8–4.6)	4.2 (1.5–9)
Positive margins (%)	6%	4%	11%
Clavien–Dindo I–II	3 (19%)	2 (8%)	3 (33%)
Clavien–Dindo III–IV[b]	0	1	0
Mean hospital stay[a]	5.2 (3–7)	6.4 (3–11)	6.6 (5–9)
Mean lesions number	2 (1–6)	1.5 (1–3)	1.6 (1–3)
Synchronous lesions (%)	31%	33%	22%

[a] Excluding associated diseases

[b] Reoperation

Table 4 Robot-assisted right colectomy cohort

Robot-assisted right colectomy (2013/1-6-2016)			
	<65	65–79	>80
N patients[b]	21 (35%)	34 (58%)	4 (7%)
ASA I–II (%)	18 (85%)	23 (68%)	0%
ASA III–IV (%)	3 (15%)	11 (32%)	1 (25%)
No comorbidity (%)	12 (57%)	9 (26%)	0%
1–2 comorbidity (%)	7 (33%)	18 (53%)	1 (25%)
3 or >comorbid. (%)	2 (9.5%)	7 (21%)	3 (75%)
Associated procedures	3	10	1
Lymphnode harvest.[a]	20.7 (13–30)	16 (8–25)	16.5 (15–18)
Mean oral intake	3.6	3.5	3.8
Mean hospital stay/days	6.6 (4–16)	6.7 (4–10)	6.6 (6–8)
Clavien–Dindo I–II (%)	1 (4.7%)	2 (5.8%)	2 (50%)
Clavien–Dindo III–IV[b] (%)	1 (4.7%)	0	**0**
30-day readmission (%)	1 (4.7%)	0	**0**
Conversion rate (%)	**0**	4 (11.7%)	1 (25%)
Mean operative time	193′ (145–290)	194′ (75–285)	205′ (180–220)

[a] Only for adenoca

[b] Reoperation

outcomes, identifying adults that are at increased risk of falls, hospitalizations, and other adverse outcomes, such as physical, cognitive, social, and biochemical components [51, 57, 58].

For this reason, the preoperative risk evaluation in the elderly population may be better evaluated overcoming the traditional risk assessments of the American Society of Anesthesiologists (ASA) and identifying patients susceptible to postoperative complications, institutionalization, increased length of stay, and mortality after surgery, using more appropriate geriatric scores [59–64].

A good model of approach for elderly care has to start as soon as the general practitioner (GP) considers referring the patient for surgery, thereby optimizing the health of the patient, by reviewing medication, providing dietary recommendations and smoking break advice, managing frailty if necessary. That requires multidisciplinary, preoperative, comprehensive geriatric assessment. The patient has to be

optimized in advance of surgery, about pain control and fluid therapy, and the optimization of drug regimen is otherwise useful. Elderly patients undergoing surgery are at risk of a decline in physical and/or mental functioning, which may not have been resolved at the time of discharge. Using a perioperative multidisciplinary approach, the length of stay may be reduced with fewer delayed discharges, as well as readmission rate [65].

Emergency surgery, of course, leads to higher risks of mortality and morbidity than elective surgery in elderly patients. According to different studies, the postoperative delirium in elderly patients ranges from 0 to 73%, depending on the type of surgery, and it can last up to 7 days and about 25% of elderly patients developing delirium postoperatively may continue to have symptoms for up to 6 months after hospital discharge. Mortality is about twice as high in emergency cases [66–69]. Geriatric events occurred in 1.0–25.5% of surgical cases according to cancer location, with the highest frequency noted for cancers requiring major abdominal surgery [70].

As with every observational study, our findings remain subject to potential bias, often the cohort age groups are not homogeneous respect to ASA score, comorbidities, or cancer stage. But the aim of this study was to evaluate the feasibility and safety of robotic approach in elderly population.

According to our data, we can assert that age is not a contraindication for major surgery and for a minimally invasive robotic-assisted approach. Anyhow, as major abdominal surgery in the elderly and frail patients is related to a higher risk of morbidity and mortality, they may benefit from an integrated, team-based approach. This should comprise geriatricians, anesthesiologists, oncologists, and surgeons working together to optimize drugs management, physical conditioning, and social support [71–74]. These models may reduce the overall morbidity and acute geriatric events as well as other complications, including total hospitalization length [75, 76].

Minimally invasive surgery (MIS) characterized by small incisions has provided many benefits for different kinds of surgeries and for oncologic diseases too, including colorectal, urologic, gynecologic, and others [46, 49, 77–80].

MIS advantages compared to open surgery include less intraoperative blood loss, faster postoperative bowel function, shorter length of hospital stay, less postoperative pain, fewer wound infections, as well as lower incidence of postoperative pneumonia and incidence of postoperative cardiac complications. However, severe complications in patients presenting high frailty remain similar [46, 81]. The faster recovery observed is in several cases the result of different strategies, in particular the enhanced recovery (ERAS) programs [82].

Robotic surgery has to be considered as the natural evolution of conventional MIS laparoscopy/thoracoscopy, consisting of a computer interface to facilitate intuitive movements similar to conventional open surgery. At present, there is no evidence that robotic surgery has to be considered better than conventional minimally invasive surgery, with only a few randomized clinical trials performed. Reports comparing robotics to laparotomy give interesting outcomes about reducing operative blood loss, complication rates, shorter hospital stay [83–85]. In many cases, the overall operative times and costs are increased [86].

Although the available data for comparing robotics to laparoscopy are insufficient, some authors reported benefits of robotics over standard laparoscopy in the treatment of endometrial cancer, [84], nephrectomy [41], hepatic resections [43], rectal resections [44], and in obese and morbidly obese patients [87]. Robotic surgery gets an increase MIS access to patients, reducing the overall conversion rate and learning curve, compared to conventional laparoscopy [88].

As robotic surgery in some cases may require steep Trendelenburg position and more prolonged operative time, there are concerns about respiratory and cardiovascular systems, especially in the elderly. A case of cerebral edema following robotic surgery was reported [89] and risk of blindness in patients suffering from moderate or high-pressure glaucoma [90]. Despite these reports, most data support the safety of robotic surgery in the elderly [91].

Although elderly patients may particularly benefit from MIS, the adoption of standard laparoscopy is not widely diffused, as it requires highly skilled surgeons, especially in high-risk patients, such as those with cancer, obesity, and the elderly. Robotic surgery probably will decrease the use of laparotomy in the future.

The oncologic safety of robotic surgery is demonstrated to be the same of open surgery or laparoscopic surgery, according to the results of Boggess's study, with a five-year follow-up of post-robotic surgery in endometrial cancer context [92]. Nonetheless some data showed that elderly patients who survive the first year after surgery have the same cancer-related survival as younger patients [56]. After two years of follow-up, the data suggest that robotic surgery in elderly patients is safe from an oncology point of view in terms of comparable rates of progression-free survival [46].

Other important considerations are costs evaluation (direct and overall) and choice of resource allocation (high-volume surgical department and multidisciplinary use programs). Some authors have demonstrated that the average cost for the surgical treatment of an endometrial cancer (hysterectomy) was highest for laparotomy, followed by robotic and standard laparoscopy, also in elder people [83, 93, 94].

Conclusions

The elderly and frail population, especially if affected by oncologic diseases, continues to grow, presenting an increased risk of major complications after surgical treatment. Benefits of minimally invasive surgery (MIS) compared to open surgery have demonstrated to improve the short-term outcomes in selected patients, especially lower perioperative complications and earlier recovery, resulting in improving the quality of life. These benefits were demonstrated in elderly population too. The high conversion rate and long learning curve of laparoscopy may be overcome by robotic surgery that represents the natural evolution of minimal access surgery, with the addition of a computer interface between the surgeon and the patient.

In our review, robot-assisted surgery is a safe and effective technique for the aging patient population, especially for major abdominal cancer surgery. There was no increased risk of death or morbidity compared to younger patients in the three groups examined. An higher conversion rate was observed in our experience for patients 65–79 years. Prolonged operative time and in any cases steep positions (Trendelenburg) have not represented a problem for the majority of patients. Nevertheless, considering the high direct costs, minimally invasive robot-assisted surgery should be done on a case-by-case basis, tailored to each patient with their specific histories and comorbidities.

In clinical practice, the decision for surgical treatment in elderly patients must also be made on a case-by-case basis. A multidisciplinary approach is the best pathway of managing; efforts reducing associated morbidity are essential. In conclusion, one may never be too old to have a minimally invasive robotic approach.

Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Statement of human and animal rights The study was approved by the local Human Investigation Committee and complete information regarding it was clearly explained.

Informed consent A written formal consent was obtained from all the subjects enrolled.

References

1. Office for National Statistics. Ageing—fastest increase in the 'oldest old'. http://www.ons.gov.uk/ons/dcp171776_258607.pdf
2. Stein JP, Lieskovsky G, Cote R et al (2001) Radical cystectomy in the treatment of invasive bladder cancer: long-term results in 1054 patients. J Clin Oncol 19:666–675
3. Yee KW, Pater JL, Pho L et al (2003) Enrollment of older patients in cancer treatment trials in Canada: why is age a barrier? J Clin Oncol 21:1618–1623
4. United States Census. U.S. Census Bureau projections show a slower growing, older, more diverse nation a half century from now. http://www.census.gov/newsroom/releases/archives/population/cb12-243.html
5. Smith BD, Smith GL, Hurria A et al (2009) Future of cancer incidence in the United States: burdens upon an aging, changing nation. J Clin Oncol 27:2758–2765
6. Turrentine FE, Wang H, Simpson VB et al (2006) Surgical risk factors, morbidity, and mortality in elderly patients. J Am Coll Surg 203:865–877
7. Hamel MB, Henderson WG, Khuri SF et al (2005) Surgical outcomes for patients aged 80 and older: morbidity and Mortality from major noncardiac surgery. J Am Geriatr Soc 53:424–429
8. American Geriatrics Society Expert Panel on Postoperative Delirium in Older Adults (2015) Post-operative delirium in older adults: best practice statement from the American Geriatrics Society. J Am Coll Surg 220:136–148
9. Dodds C, Foo I, Jones K et al (2013) Peri-operative care of elderly patients—an urgent need for change: a consensus statement to provide guidance for specialist and non-specialist anaesthetists. Perioper Med (Lond) 2:6. doi:10.1186/2047-0525-2-6
10. Lev D, Pollock RE (2010) Managing elderly soft tissue sarcoma patients-should age drive treatment? Ann Surg Oncol 17:1725–1726
11. Lahat G, Dhuka AR, Lahat S et al (2009) Complete soft tissue sarcoma resection is a viable treatment option for select elderly patients. Ann Surg Oncol 16:2579–2586
12. Chereau E, Ballester M, Selle F et al (2011) Ovarian cancer in the elderly: impact of surgery on morbidity and survival. Eur J Surg Oncol 37:537–542
13. Fornara P, Doehn C, Frese R et al (2001) Laparoscopic nephrectomy in young-old, old-old, and oldest-old adults. J Gerontol A Biol Sci 56:M287–M291
14. Scarpa M, di Cristofaro L, Cortinovis M et al (2013) Minimally invasive surgery for colorectal cancer: quality of Life and Satisfaction with care in elderly patients. Surg Endosc 27:2911–2920
15. Mutch MG (2006) Laparoscopic colectomy in the elderly: when is too old. Clin Colon Rectal Surg 19:33–39. doi:10.1055/s-2006-939529
16. Rocco G, Weder W (2013) Lung surgery in the elderly today. Lung Cancer 80:115–119
17. Korc-Grodzicki B, Downey RJ, Shahrokni A et al (2014) Surgical considerations in older adults with cancer. J Clin Oncol 32:2647–2653
18. Truta B, Allen BA, Conrad PG et al (2005) A comparison of the phenotype and genotype in adenomatous polyposis patients with and without a family history. Fam Cancer 4:127–133
19. Thirlwell C, Howarth KM, Segditsas S et al (2007) Investigation of pathogenic mechanisms in multiple colorectal adenoma patients without germline APC or MYH/MUTYH mutations. Br J Cancer 96:1729–1734
20. Rocca A, Calise F, Marino G et al (2014) Primary giant hepatic neuroendocrine carcinoma: a case report. Int J Surg 12(Suppl 1):S218–S221
21. Cattaneo F, Guerra G, Parisi M et al (2015) Expression of formyl-peptide receptors in human lung carcinoma. Anticancer Res 35:2769–2774
22. Rippa E, Altieri F, Chiara Di Stadio S et al (2015) Ectopic expression of gastrokine 1 in gastric cancer cells up-regulates tight and adherens junction proteins network. Pathol Res Pract 211:577–583

23. Moccia F, Dragoni S, Lodola F et al (2012) Store-dependent Ca2+ entry in endothelial progenitor cells as a perspective tool to enhance cell-based therapy and adverse tumour vascularisation. Curr Med Chem 19:5802–5818
24. Lodola F, Laforenza U, Bonetti E et al (2012) Store-operated ca(2+) entry is remodelled and controls in vitro angiogenesis in endothelial progenitor cells isolated from tumoral patients. PLoS ONE 7:e42541
25. Dragoni S, Laforenza U, Bonetti E et al (2014) Enhanced expression of Stim, Orai, and TRPC transcripts and proteins in endothelial progenitor cells isolated from patients with primary myelofibrosis. PLoS ONE 9:e91099
26. Moccia F, Lodola F, Dragoni S et al (2014) Ca2+ signalling in endothelial progenitor cells: a novel means to improve cell-based therapy and impair tumour vascularisation. Curr Vasc Pharmacol 12:87–105
27. Dragoni S, Turin I, Laforenza U et al (2014) Store-operated ca(2+) entry does not control proliferation in primary cultures of human metastatic renal cellular carcinoma. Biomed Res Int 2014:739494
28. Moccia F, Zuccolo E, Poletto V et al (2015) Endothelial progenitor cells support tumour growth and metastatisation: implications for the resistance to anti-angiogenic therapy. Tumour Biol 36:6603–6614
29. Dragoni S, Reforgiato M, Zuccolo E et al (2015) Dysregulation of VEGF-induced pro-angiogenic Ca2+ oscillations in primary myelofibrosis-derived endothelial colony forming cells. Exp Hematol 43:1019–1030
30. Zuccolo E, Bottino C, Diofano F et al (2016) Constitutive store-operated Ca2+ entry leads to enhanced nitric oxide production and proliferation in infantile hemangioma-derived endothelial colony forming cells. Stem Cells Dev 25:301–319
31. Poletto V, Dragoni S, Lim D et al (2016) Endoplasmic reticulum Ca2+ handling and apoptotic resistance in tumor-derived endothelial colony forming cells. J Cell Biochem 117:2260–2271. doi:10.1002/jcb.25524
32. Moccia F, Zuccolo E, Poletto V et al (2016) Targeting Stim and Orai proteins as an alternative approach in anticancer therapy. Curr Med Chem 23:3450–3480
33. Berra-Romani R, Avelino-Cruz JE, Raqeeb A et al (2013) Ca2+-dependent nitric oxide release in the injured endothelium of excised rat aorta: a promising mechanism applying in vascular prosthetic devices in aging patients. BMC Surg 13(Suppl 2):S40
34. Moccia F, Dragoni S, Cinelli M et al (2013) How to utilize Ca2+ signals to rejuvenate the repairative phenotype of senescent endothelial progenitor cells in elderly patients affected by cardiovascular diseases: a useful therapeutic support of surgical approach? BMC Surg 13(Suppl 2):S46
35. Ballesta Lopez C, Cid JA, Poves I et al (2003) Laparoscopic surgery in the elderly patient. Surg Endosc 17:333–337
36. Venkat R, Edil BH, Schulick RD et al (2012) Laparoscopic distal pancreatectomy is associated with significantly less overall morbidity compared to the open technique: a systematic review and meta-analysis. Ann Surg 255:1048–1059
37. Permpongkosol S, Bagga HS, Romero FR et al (2006) Laparoscopic versus open partial nephrectomy for the treatment of pathological T1N0M0 renal cell carcinoma: a 5-year survival rate. J Urol 176:1984–1988
38. Giulianotti PC, Coratti A, Angelini M et al (2003) Robotics in general surgery: personal experience in a large community hospital. Arch Surg 138:777–784
39. Ballantyne GH (2007) Telerobotic gastrointestinal surgery: phase 2–safety and efficacy. Surg Endosc 21:1054–1062
40. Patriti A, Ceccarelli G, Ceribelli C et al (2011) Robot-assisted laparoscopic management of cardia carcinoma according to Siewert recommendations. Int J Med Robot 7(2):170–177
41. Ceccarelli G, Codacci-Pisanelli M, Patriti A et al (2013) Robotic-assisted transperitoneal nephron-sparing surgery for small renal masses with associated surgical procedures: surgical technique and preliminary experience. Updates Surg 65:183–190
42. Caruso S, Patriti A, Roviello F et al (2016) Laparoscopic and robot-assisted gastrectomy for gastric cancer: current considerations. World J Gastroenterol 22:5694–5717
43. Casciola L, Patriti A, Ceccarelli G et al (2011) Robot-assisted parenchymal-sparing liver surgery including lesions located in the posterosuperior segments. Surg Endosc 25:3815–3824
44. Bianchi PP, Petz W, Luca F et al (2014) Laparoscopic and robotic total mesorectal excision in the treatment of rectal cancer. Brief review and personal remarks. Front Oncol 6:98
45. Coratti A, Di Marino M, Coratti F et al (2016) Initial experience with robotic pancreatic surgery: technical feasibility and oncological implications. Surg Laparosc Endosc Percutan Tech 26:31–37
46. Lavoue V, Zeng X, Lau S et al (2014) Impact of robotics on the outcome of elderly patients with endometrial cancer. Gynecol Oncol 133:556–562
47. Vaknin Z, Perri T, Lau S et al (2010) Outcome and quality of life in a prospective cohort of the first 100 robotic surgeries for endometrial cancer, with focus on elderly patients. Int J Gynecol Cancer 20:1367–1373
48. Uyar D, Frasure HE, Markman M et al (2005) Treatment patterns by decade of life in elderly women (≥70 years of age) with ovarian cancer. Gynecol Oncol 98:403–408
49. Sundararajan V, Hershman D, Grann VR et al (2002) Variations in the use of chemotherapy for elderly patients with advanced ovarian cancer: a population-based study. J Clin Oncol 20:173–178
50. Rogers CG, Sammon JD, Sukumar S et al (2013) Robot assisted radical prostatectomy for elderly patients with high risk prostate cancer. Urol Oncol 31:193–197
51. Fried LP, Tangen CM, Walston J et al (2001) Frailty in older adults: evidence for a phenotype. J Gerontol A Biol Sci 56:M146–M156
52. Spyropoulou D, Pallis AG, Leotsinidis M et al (2014) Completion of radiotherapy is associated with the Vulnerable Elders Survey-13 score in elderly patients with cancer. J Geriatr Oncol 5:20–25
53. Puts MT, Hardt J, Monette J et al (2012) Use of geriatric assessment for older adults in the oncology setting: a systematic review. J Natl Cancer Inst 104:1133–1163
54. Polanczyk CA, Marcantonio E, Goldman L et al (2001) Impact of age on perioperative complications and length of stay in patients undergoing noncardiac surgery. Ann Intern Med 134:637–643
55. Finlayson E, Fan Z, Birkmeyer JD (2007) Outcomes in octogenarians undergoing high-risk cancer operation: a national study. J Am Coll Surg 205:729–734
56. Dekker JW, van den Broek CB, Bastiaannet E et al (2011) Importance of the first postoperative year in the prognosis of elderly colorectal cancer patients. Ann Surg Oncol 18:1533–1539
57. Buchner DM, Wagner EH (1992) Preventing frail health. Clin Geriatr Med 8:1–17
58. Campbell AJ, Buchner DM (1997) Unstable disability and the fluctuations of frailty. Age Ageing 26:315–318
59. Afilalo J, Eisenberg MJ, Morin JF et al (2010) Gait speed as an incremental predictor of mortality and major morbidity in elderly patients undergoing cardiac surgery. J Am Coll Cardiol 56:1668–1676
60. Makary MA, Segev DL, Pronovost PJ et al (2010) Frailty as a predictor of surgical outcomes in older patients. J Am Coll Surg 210:901–908
61. Lee DH, Buth KJ, Martin BJ et al (2010) Frail patients are at increased risk for mortality and prolonged institutional care after cardiac surgery. Circulation 121:973–978

62. Robinson TN, Wallace JI, Wu DS et al (2011) Accumulated frailty characteristics predict postoperative discharge institutionalization in the geriatric patient. J Am Coll Surg 213:37–42
63. Revenig LM, Canter DJ, Taylor MD et al (2013) Too frail for surgery? Initial results of a large multidisciplinary prospective study examining preoperative variables predictive of poor surgical outcomes. J Am Coll Surg 217:665–670
64. Kim SW, Han HS, Jung HW et al (2014) Multidimensional frailty score for the prediction of postoperative mortality risk. JAMA Surg 149:633–640
65. Harari D, Hopper A, Dhesi J et al (2007) Proactive care of older people undergoing surgery ('POPS'): designing, embedding, evaluating and funding a comprehensive geriatric assessment service for older elective surgical patients. Age Ageing 36:190–196
66. Ford PN, Thomas I, Cook TM et al (2007) Determinants of outcome in critically ill octogenarians after surgery: an observational study. Br J Anaesth 99:824–829. doi:10.1093/bja/aem307
67. Dyer CB, Ashton CM, Teasdale TA (1995) Postoperative delirium. A review of 80 primary data-collection studies. Arch Intern Med 155:461–465
68. Dodds C, Kumar CM, Servin F (2007) Oxford Anaesthesia Library: anaesthesia for the elderly patient. Oxford University Press, Oxford
69. Levkoff SE, Marcantonio ER (1994) Delirium: a major diagnostic and therapeutic challenge for clinicians caring for the elderly. Compr Ther 20:550–557
70. Kassin MT, Owen RM, Perez SD et al (2012) Risk factors for 30-day hospital readmission among general surgery patients. J Am Coll Surg 215:322–330
71. Extermann M, Aapro M, Bernabei R et al (2005) Task force on CGA of the International Society of Geriatric Oncology: use of comprehensive geriatric assessment in older cancer patients: recommendations from the task force on CGA of the International Society of Geriatric Oncology (SIOG). Crit Rev Oncol Hematol 55:241–252
72. Chow WB, Rosenthal RA, Merkow RP et al (2012) American College of Surgeons National Surgical Quality Improvement Program; American Geriatrics Society: optimal preoperative assessment of the geriatric surgical patient: A best practices guideline from the American College of Surgeons National Surgical Quality Improvement Program and the American Geriatrics Society. J Am Coll Surg 215:453–466
73. Solomon DH, Burton JR, Lundebjerg NE, Eisner J (2000) The new frontier: increasing geriatrics expertise in surgical and medical specialties. J Am Geriatr Soc 48:702–704
74. Bell RH Jr, Drach GW, Rosenthal RA (2011) Proposed competencies in geriatric patient care for use in assessment for initial and continued board certification of surgical specialists. J Am Coll Surg 213:683–690
75. Marcantonio ER, Flacker JM, Wright RJ et al (2001) Reducing delirium after hip fracture: a randomized trial. J Am Geriatr Soc 49:516–522
76. Miura LN, DiPiero AR, Homer LD (2009) Effects of a geriatrician-led hip fracture program: improvements in clinical and economic outcomes. J Am Geriatr Soc 57:159–167
77. Shuford MD, McDougall EM, Chang SS et al (2004) Complications of contemporary radical nephrectomy: comparison of open vs. laparoscopic approach. Urol Oncol 22:121–126
78. Allardyce RA, Bagshaw PF, Frampton CM et al (2010) Australasian Laparoscopic Colon Cancer Study Group. Australasian laparoscopic colon cancer study shows that elderly patients may benefit from lower postoperative complication rates following laparoscopic versus open resection. Br J Surg 97:86–91
79. She WH, Poon JT, Fan JK et al (2013) Outcome of laparoscopic colectomy for cancer in elderly patients. Surg Endosc 27:308–312
80. Scribner DR Jr, Walker JL, Johnson GA et al (2001) Surgical management of early-stage endometrial cancer in the elderly: is laparoscopy feasible? Gynecol Oncol 83:563–568
81. Obeid NM, Azuh O, Reddy S et al (2012) Predictors of critical care-related complications in colectomy patients using the National Surgical Quality Improvement Program: exploring frailty and aggressive laparoscopic approaches. J Trauma Acute Care Surg 72:878–883
82. Gonzalez-Ayora S, Pastor C, Guadalajara H et al (2016) Enhanced recovery care after colorectal surgery in elderly patients. Compliance and outcomes of a multicenter study from the Spanish working group on ERAS. Int J Colorectal Dis 31:1625–1631. doi:10.1007/s00384-016-2621-7
83. Lau S, Vaknin Z, Ramana-Kumar AV et al (2012) Outcomes and cost comparisons after introducing a robotics program for endometrial cancer surgery. Obstet Gynecol 119:717–724
84. Boggess JF, Gehrig PA, Cantrell L et al (2008) A comparative study of 3 surgical methods for hysterectomy with staging for endometrial cancer: robotic assistance, laparoscopy, laparotomy. Am J Obstet Gynecol 199:360 e1–360 e9
85. Biere SS, van Berge Henegouwen MI, Maas KW et al (2012) Minimally invasive versus open oesophagectomy for patients with oesophageal cancer: a multicentre, open-label, randomised controlled trial. Lancet 379:1887–1892
86. Orlando G, Gervasi R, Luppino IM et al (2014) The role of a multidisciplinary approach in the choice of the best surgery approach in a super-super-obesity case. Int J Surg 12:103–106. doi:10.1016/j.ijsu.2014.05.037
87. Gehrig PA, Cantrell LA, Shafer A et al (2008) What is the optimal minimally invasive surgical procedure for endometrial cancer staging in the obese and morbidly obese woman? Gynecol Oncol 111:41–45
88. Ahlering TE, Skarecky D, Lee D et al (2003) Successful transfer of open surgical skills to a laparoscopic environment using a robotic interface: initial experience with laparoscopic radical prostatectomy. J Urol 170:1738–1741
89. Barr C, Madhuri TK, Prabhu P et al (2014) Cerebral oedema following robotic surgery: a rare complication. Arch Gynecol Obstet 290:1041–1044
90. Rupp-Montpetit K, Moody ML (2005) Visual loss as a complication of non-ophthalmic surgery: a review of the literature. Insight 30:10–17
91. Doo DW, Guntupalli SR, Corr BR et al (2015) Comparative surgical outcomes for endometrial cancer patients 65 years old or older staged with robotics or laparotomy. Ann Surg Oncol 22:3687–3694
92. Kilgore JE, Jackson AL, Ko EM et al (2013) Recurrence-free and 5-year survival following robotic-assisted surgical staging for endometrial carcinoma. Gynecol Oncol 129:49–53
93. Amato B, Villa F, Compagna R et al (2002) Organizational models in robotica assisted surgery. IJCI Int J Clin Investig 10:45–48
94. Rispoli C, Rocco N, Iannone L et al (2009) Developing guidelines in geriatric surgery: role of the grade system. BMC Geriatr 9(Suppl.1):A99