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New perspectives in the management of small cell lung cancer

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Abstract

The treatment of small cell lung cancer (SCLC) is a challenge for all specialists involved. New treatments have been added to the therapeutic armamentarium in recent months, but efforts must continue to improve both survival and quality of life. Advances in surgery and radiotherapy have resulted in prolonged survival times and fewer complications, while more careful patient selection has led to increased staging accuracy. Developments in the field of systemic therapy have resulted in changes to clinical guidelines and the management of patients with advanced disease, mainly with the introduction of immunotherapy. In this article, we describe recent improvements in the management of patients with SCLC,

review current treatments, and discuss future lines of research.

Key Words: Small cell lung cancer; Whole-brain radiotherapy; Prophylactic cranial irradiation; Stereotactic body radiotherapy; Immunotherapy; Atezolizumab; Durvalumab

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Core Tip: The treatment of small cell lung cancer (SCLC) continues to be a challenge. Recent studies have described survival benefits achieved by new treatments or combinations of treatments that are both safe and effective. Immunotherapy has a new role in SCLC. Nevertheless, continued research efforts are needed. Here, we review the current management of SCLC and discuss recent improvements and future lines of research.

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INTRODUCTION

Small cell lung cancer (SCLC) accounts for 14% of all lung cancers[1,2], and most cases are associated with tobacco use[3]. Although the global incidence of SCLC is falling, the ratio of male to female cases is currently 1:1[1,2]. SCLC is a fast-growing cancer, and most patients have extensive disease when diagnosed. In approximately one-third of cases, the cancer is limited to the thorax and can be treated with concurrent chemotherapy and radiotherapy. Just a small percentage of patients are amenable to surgery and adjuvant therapy. The goal of treatment in patients with extensive disease is to alleviate symptoms and prolong survival, although long-term survivorship in this setting is rare[4].

LIMITED-STAGE DISEASE

Surgical treatment of SCLC

Early-stage SCLC, stage I and IIA (T1-2N0M0) SCLC in the American Joint Committee on Cancer/International Union Against Cancer classification[5-7], accounts for 7% of all SCLCs and 0.29% of all lung cancers[8]. Numerous studies have shown excellent survival rates in patients with SCLC cT1-2N0M0 treated with surgery as part of a multimodal approach[6,9-28] (Table 1).

Surgical resection followed by adjuvant therapy is currently recommended by most clinical guidelines for operable stage I and IIA SCLC. Choice of adjuvant treatment varies according to pathologic tumor-node-metastasis stage: Chemotherapy for pN0, chemotherapy ± radiotherapy for pN1 and chemoradiotherapy for pN2[29-32] (Figure 1). The indications for the surgical treatment of SCLC can be summarized as follows: (1) Intraoperative diagnosis of a pulmonary SCLC nodule. Between 3% and 5% of SCLCs present as a pulmonary nodule. Multidisciplinary treatment involving surgical resection, systematic nodal dissection, and adjuvant chemotherapy or chemoradiotherapy can achieve survival rates comparable to those seen in non-SCLC[8]; (2) Diagnosis of stage I or IIA SCLC. Local or regional recurrence[33-39] (tumor and/or hilar-mediastinal lymph nodes) is the most common form of disease in patients who relapse after complete remission with chemoradiotherapy[40-45]. Surgery as part of a multimodal approach achieves better local disease control[46-50] than chemoradiotherapy[51-54]; (3) Mixed histology (SCLC with a non-SCLC component). Between 2% and 28% of patients have mixed SCLC/non-SCLC[55-59]. Recurrence or failure to respond to first-line chemotherapy is likely to be due to the non-SCLC component; and (4) Salvage surgery for local chemo-resistant SCLC or exclusively local recurrence after response to chemoradiotherapy. Selected patients in this setting might benefit from surgical resection[60-62].

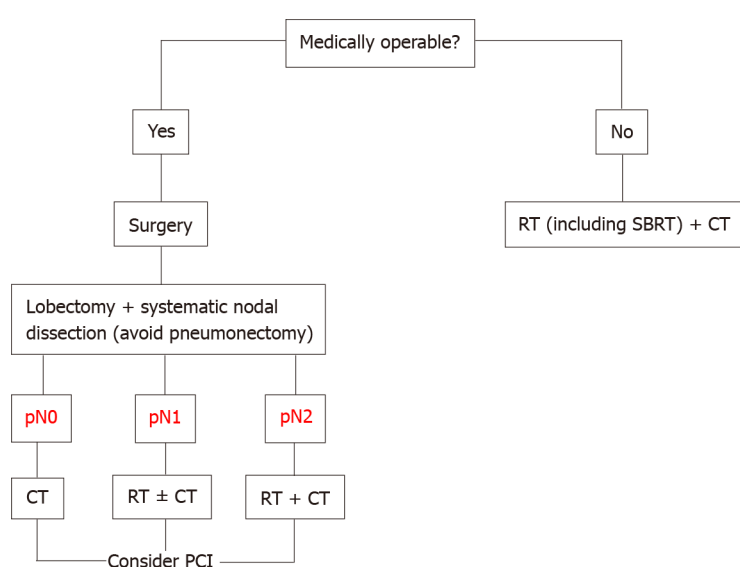
Lobectomy is the preferred procedure for surgical resection, as it is associated with significantly better survival than sublobar resection[40,45,49,54,63]. The significant discrepancies observed between clinical and pathologic stages (mainly due to undetected lymph node metastasis before surgery) highlight the importance of accurate clinical nodal staging and systematic lymph node dissection[47, 64]. The recommendations for ruling out hilar and mediastinal lymph node involvement are very similar across the different guidelines. Ideally, clinical staging should be performed using semi-invasive

Table 1 Surgical and survival rates for patients with small cell lung cancer (period time revised 1999-2020) - (dash), lack of information or details

Ref.	Study type & time period. LoE	Inclusion criteria	Number of patients	Neoadjuvant/adjuvant treatments	PCI	Survival data
Jin <i>et al</i> [9], 2018	RS; SEER 2004-2013; 3A	cI-II	<i>n</i> = 2129; S: 387; RT 1032; S + RT: 154; No S or RT: 556	-	-	5-yr OS T1N0: 46.0% S <i>vs</i> 23.8% RT; 5-yr OS T2N0: 42.6% S <i>vs</i> 24.7% RT; T3N0 or T1-2N1 (stage IIB) patients treated with S did not have higher 5-yr OS rates than those treated with RT
Yang <i>et al</i> [10], 2018	RS; NCDB 2003-2011; Propensity score match S + AC <i>vs</i> CRT; 3A	cT1-2N0M0	S + AC: 501; CRT: 501	S + AC: 501	-	5-yr OS: 47.6% S + AC <i>vs</i> 29.8% CRT (<i>P</i> < 0.01)
Ahmed <i>et al</i> [11], 2017	RS; SEER 2007-2013; 3A	Stage I SCLC	<i>n</i> = 1902; S: 427; S + RT: 115	-	-	MST: 50 mo (S); MST: 60 + mo (S + RT)
Wakeam <i>et al</i> [12], 2017	RS; NCDB 2004-2013; 3A	cT1-2N0M0	<i>n</i> = 5079	-	-	MST: 25.3 mo
Wakeam <i>et al</i> [13], 2017	RS; NCDB 2004-2013; Stage-specific propensity score match S <i>vs</i> NST; 3A	cI-III	<i>n</i> = 2619	No AD treatment 24% NC or NR 4%; AC 27%; AR 1%; ACR 32%; NC or NR and AC or AR 2%; Other 10%	-	MST cI 38.6 <i>vs</i> 22.9 mo S <i>vs</i> NST; MST cII 23.4 <i>vs</i> 20.7 mo S <i>vs</i> NST; MST cIIIA 21.7 <i>vs</i> 16.0 mo S <i>vs</i> NST
Combs <i>et al</i> [14], 2015	RS; NCDB 1998-2011; 3A	cT1-3N0-2 SCLC	<i>n</i> = 2476; S 841 cIA, 168 cIB	All; S: 68%	-	5-yr OS: 54% (cIA); 36% (cIB)
Ogawa <i>et al</i> [15], 2012	RS; Institutional 1995-2008; 4	cI-III; pI-III SCLC	<i>n</i> = 28 (23 SCLC before S); S 21 cI, 5 cII, 7 cIIIA	NC 8; AC 19, ACR 2	-	5-yr OS 47%
Ju <i>et al</i> [16], 2012	RS; Institutional 1990-2009; 4	pI-III	<i>n</i> = 34	NC 3; AC 1, AR 19, 10 CRT	-	5-yr OS 66%
Vallièrès <i>et al</i> [6], 2009	RS; IASLC 1990-2000; 3A	Resected SCLC	<i>n</i> = 349 (68 pIA, 91 pIB)	-	-	5-yr OS: 53% (pIA); 44% (pIB)
Lim <i>et al</i> [17], 2008	RS; Institutional 1980-2007; 4	cI-cIIIB	<i>n</i> = 59	AC 13; AR 2; ACR 1	-	5-yr OS for all patients 52%; No difference in 5-yr survival across; cI and cN categories; No difference in 5-yr survival across; cI to cIII stages
Wang <i>et al</i> [18], 2007	RS; Institutional; 4	pI-III	<i>n</i> = 122	QT & CRT (not specified)	-	MST 50 mo; 5-yr OS 66%
Veronesi <i>et al</i> [19], 2007	RS; Institutional; 4	cI-IIIA	<i>n</i> = 23	AC all	-	MST 24 mo
Tsuchiya <i>et al</i> [20], 2005	Prospective phase II trial; 1991-1996; 2B	cI-IIIA	<i>n</i> = 62	AC 42 (69%)	-	MST not reached in pI; MST 449 d for pII; MST 712 d for pIIIA; 3-yr OS 61%; 3-yr survival rate cI, cII, cIIIA 68%, 56% and 13% respectively
Brock <i>et al</i> [21], 2005	RS; Institutional 1976-2002; 4	Resected SCLC	<i>n</i> = 82 (24 stage I, S + AC)	AC 55%	23%	5-yr OS: 86% (platinum AC); 42% (non-platinum AC)
Nakamura <i>et al</i> [22], 2004	RS; Institutional; 4	cI-III SCLC	<i>n</i> = 69	S 37, NC 32, AC 41, ACR 7	-	5-yr survival 48.9% cI, 33.3% cII, 20.2% cIIIA, 0% cIIIB
Badzio <i>et al</i> [23], 2004	Comparative RS; Institutional 1984-1996; 4	cI-III balanced in both, S and NST groups	<i>n</i> = 134	S 67 (all AC); NST 67 (all QT)	34% only S group	MST 22 mo (S); MST 11 mo (NST); 5-yr OS S 27%, NST 4%
Lewiński <i>et al</i> [24], 2001	R; Institutional 1976-2002; 4	cI-IIIA SCLC	<i>n</i> = 75	NC all	If CR to NC	MST N0+1 25 mo; MST N2 14 mo; MST resected 18 mo; 5-yr OS resected 29%
Cataldo <i>et al</i> [25], 2000	RS; Institutional 1982-1992; 4	cI-III SCLC	<i>n</i> = 60	AC 88%; pII AR (11%); pIII AR (21%)	41%	5-yr survival rate 40% pI, 36% pII and 15% pIII

Inoue <i>et al</i> [26], 2000	RS; Institutional 1975-1994; 4	Resected SCLC	n = 91 (32 cIA, 30 cIB)	All 78%	5.5%	MST 53 mo, 5-yr OS 49% (cIA); MST 25 mo, 5-yr OS 47% (cIB)
Kobayashi <i>et al</i> [27], 2000	RS; Institutional 1982-1992; 4	cI-III SCLC	n = 59	NC 71%	-	5-yr survival rate 55% pI, 33% pII, 23% pIII
Eberhardt <i>et al</i> [28], 1999	Prospective phase II trial; Institutional 1991-1995; 2B	cIB-cIIIB	n = 46	IB/IIA had NC + S; IIB/IIIA had NCR + S	-	MST all patients 36 mo; MST R0 patients 68 mo; 5-yr survival rate all patients 46%; 5-yr survival rate R0 patients 63%

ACR: Adjuvant chemoradiotherapy; AD: Adjuvant; AC: Adjuvant chemotherapy; cIA: Clinical stage IA; cIB: Clinical stage IB; CR: Complete response; CRT: Chemoradiotherapy; IASLC: International Association for the Study of Lung Cancer; ISC-LCSG: The Lung Cancer Study Group of the International Society of Chemotherapy; LoE: Level of evidence; MST: Median survival time; NC: Neoadjuvant chemotherapy; NST: Non-surgical treatment; NCDB: National Cancer Data Base; OS: Overall survival; PCI: Prophylactic cranial irradiation; pIA: Pathologic stage IA; pIB: Pathologic stage IB; pII: Pathologic stage II; pIIIA: Pathologic stage IIIA; pIIIB: Pathologic stage IIIB; QT: Chemotherapy; R0: Complete resection; RS: Retrospective study; RT: Radiotherapy; S: Surgery; SCLC: Small cell lung cancer; SEER: Surveillance, Epidemiology, and End Results database.



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Figure 1 Proposed algorithm for the treatment of early-stage small cell lung cancer focused on surgical treatment. CT: Chemotherapy; PCI: Prophylactic cranial irradiation; RT: Radiotherapy; SBRT: Stereotactic body radiation therapy.

techniques that enable biopsy and the pathologic study of lymph nodes (*e.g.*, transbronchial ultrasound and esophageal echoendoscopy) and invasive techniques such as video mediastinoscopy, anterior mediastinotomy, and videothoracoscopy.

Radiotherapy in limited-stage SCLC

Thoracic radiotherapy and stereotactic body radiotherapy in early-stage SCLC: SCLC is usually classified as limited-stage (LS) or extensive-stage (ES) disease[65]. With adequate treatment, overall survival (OS) is 16-22 mo in patients with LS-SCLC and 8-13 mo in those with ES-SCLC. The corresponding 5-year survival rates are < 20% and < 2%[66]. Radiotherapy is associated with better OS when given in the first few weeks after the start of chemotherapy (ideally during cycle 1 and never later than cycle 3), and the shorter the duration the better[67].

Hypofractionated radiotherapy is well tolerated and produces similar response rates to standard fractionation. Proposed schedules include 40 Gy in 16 fractions with chemotherapy and prophylactic cranial irradiation (PCI)[68] and 55 Gy in 25 once-daily fractions, also with chemotherapy and PCI[69]. Higher complete response rates and longer OS have been observed for hyperfractionated *vs* hypofractionated radiotherapy (45 Gy in 30 fractions twice daily *vs* 42 Gy in 15 fractions twice daily), but the differences were not statistically significant[70].

Treatment must be individualized. Some clinical guidelines recommend surgery and adjuvant chemotherapy for stage I and IIA disease[30,71]. This combination has achieved OS rates of 50%-70%[20, 21,72,73]. Nonetheless, stereotactic body radiotherapy (SBRT) should be considered in patients who are unfit for or refuse surgery, as it is not inferior to conventional treatment and has an acceptable safety

profile (toxicity < grade 3)[74-80]. Although the evidence is based on small series, SBRT can achieve local control rates > 85%. No clear benefit, however, has been observed for OS (63%-83% at 1 year, 35%-76% at 2 years, and 21%-26% at 3 years) (Table 2). This could have several explanations. First, SCLC is a fast-spreading tumor (associated with distant metastases in 50% of cases), requiring clinicians to consider neoadjuvant or adjuvant chemotherapy (preferably adjuvant in the case of SBRT due to its short treatment time), particularly in the case of tumors > 2 cm[77-81]. Adjuvant chemotherapy can improve OS by up to 25%[82]. Second, the disease may have been initially understaged. Thus, staging with positron emission tomography-computed tomography (CT) and mediastinoscopy/endobronchial ultrasound is recommended before proposing surgery or SBRT. SBRT should be planned using intensity-modulated techniques (*e.g.*, intensity-modulated radiotherapy, volumetric modulated arc therapy) and delivered with image-guided inter- and/or intrafraction monitoring (*e.g.*, Conebeam, ExacTrac) and respiratory control (*e.g.*, four-dimensional CT, deep inspiration breath hold, active breathing control, gating). The number of fractions can vary, but a biologically effective dose of >100 Gy must be delivered to the isocenter of the tumor. Because SCLC is highly radiosensitive, some groups have suggested using a lower dose, particularly in patients with ultracentral tumors[83].

PCI

Patients with SCLC are at high risk of brain metastases (BM)[84,85]. Research into the potential of PCI began in the late 1970s[86]. Brain magnetic resonance imaging (MRI) should be performed after chemoradiotherapy or systemic therapy[87], as 21.8%-32.5% of patients who achieve complete response subsequently develop BM[88,89]. A meta-analysis published by Aupérin *et al*[90] in 1999 showed that PCI was associated with a reduced incidence of BM at 3 years (59% *vs* 33%) and a 5.4% increase in OS. Subsequent meta-analyses have shown similarly favorable results for PCI in patients who had responded to treatment[91-94]. Most of these studies, however, were published before the introduction of restaging with brain MRI, and therefore the true benefit of PCI in LS-SCLC is not so clear[95,96]. Nonetheless, retrospective studies have described beneficial effects for PCI in patients with a previous negative brain MRI scan[97,98]. Patients who have undergone complete resection should benefit from PCI, except patients with stage I disease, who have a low risk of BM[99-101]. There is a growing interest in the use of brain MRI and stereotactic irradiation rather than PCI in patients with LS-SCLC[102], but prospective randomized trials are needed.

Concomitant treatment in locally advanced disease

Radical treatment with chemotherapy and concomitant radiotherapy are recommended for patients with stage IIB-IIIC disease in good general health[4,103]. Eighty percent of patients with mediastinal involvement treated exclusively with chemotherapy experience local recurrence[104], but the addition of radiotherapy lowers this rate and increases survival[104,105]. The CONVERT trial, which compared fractionated and unfractionated radiotherapy in patients treated with cisplatin-etoposide, reported an overall response rate (ORR) of 70%-90%, an OS of 24-30 mo, and a 5-year OS rate of 25%-30%[106]. Another two trials investigated the combination of bevacizumab, an angiogenic, with conventional chemoradiotherapy, but had to be discontinued because of a relatively high incidence of severe adverse events (tracheoesophageal fistulae)[107].

Perspectives for radiotherapy in LS-SCLC

Radiotherapy with immunotherapy in LS-SCLC: Three trials are currently analyzing the combined use of radiotherapy and immunotherapy in LS-SCLC: The NRG Oncology and Alliance trial (ClinicalTrials.gov Identifier: NCT03811002) investigating chemoradiotherapy with and without atezolizumab; the phase II STIMULI trial (NCT02046733) analyzing nivolumab and ipilimumab after chemoradiotherapy and PCI; and the phase III ADRIATIC trial (NCT03703297) comparing durvalumab, durvalumab plus tremelimumab, and placebo in patients without progression after chemoradiotherapy.

Hippocampal avoidance to reduce the neurotoxicity of PCI: The role of PCI with hippocampal avoidance (HA) in patients with LS- or ES-SCLC without BM is being investigated in three phase III trials: The Dutch NKI/AVL trial (NCT01780675), the NRG Oncology CC003 trial (NCT02635009), and the Spanish PREMIER-TRIAL (NCT02397733)[108]. The Dutch group found no significant differences in recall assessed using the revised version of the Hopkins Verbal Learning Test between patients who received PCI and those who received HA-PCI[109]. Using the Free and Cued Selecting Reminding Test, the Spanish group found a significant decline in 3-mo delayed recall [22.22% *vs* 5.08%; odds ratio (OR) = 5.33; 95% confidence interval (CI): 1.44-19.65; *P* = 0.006] and total recall (20.63% *vs* 6.78%; OR = 3.57; 95%CI: 1.09-11.68; *P* = 0.02] in the PCI *vs* HA-PCI group[110]. Another potentially interesting line of research is the use of Alzheimer disease drugs to preserve cognition in patients treated with PCI[111].

Proton beam radiation therapy: In non-SCLC, proton therapy has been used to reduce doses to the heart while maintaining high doses to the tumor[112]. Proton beam radiation therapy (PBRT) is potentially beneficial in SCLC, as patients tend to have bulky central disease at diagnosis. In a study of 30 patients at the University of Pennsylvania, PBRT at a median dose of 63.9 cobalt Gy equivalents achieved a promising median OS of 28.2 mo with low toxicity[113]. These results need to be validated in

Table 2 Thoracic radiotherapy and stereotactic body radiotherapy in early-stage small cell lung cancer

Ref.	Sample size	Fractionation	QT	Prophylactic cranial irradiation	Local control	Overall survival	Disease-free survival
Videtic <i>et al</i> [76], 2013	<i>n</i> = 6	60 Gy (3 fx); 50 Gy (5 fx); 30 Gy (1 fx)	4/6	4/6	100% (1 yr)	63% (1 yr)	75% (1 yr)
Shioyama <i>et al</i> [77], 2015	<i>n</i> = 64	48 Gy (4 fx)	36/64	10/64	89% (2 yr)	76% (2 yr)	
Stahl <i>et al</i> [79], 2017	<i>n</i> = 285	48-60 Gy (3-5 fx)	130/285		35% (3 yr). 21.5% (5 yr)		
Verma <i>et al</i> [75], 2017	<i>n</i> = 74	50 Gy (5 fx)	45/74	17/74	96% (3 yr)		
Shioyama <i>et al</i> [78], 2018	<i>n</i> = 43	36-60 Gy (3-10 fx)	8/43	8/43	80.2% (2 yr)	72.3% (2 yr)	44.6% (2 yr)
Verma <i>et al</i> [74], 2019	<i>n</i> = 149	45-60 Gy (3-8 fx)	149/149		83.8% (29.2 mo)		
Newman <i>et al</i> [81], 2019	<i>n</i> = 239	BED > 100 Gy (max 8 fx)	84/239		27% (5 yr); 36% (5 yr, with QT)		
Singh <i>et al</i> [80], 2019	<i>n</i> = 21	BED 105.6 Gy (3-5 fx)	4/21		100% (1, 2, 3 yr)	73.1% (1 yr); 36.6% (2 yr)	85.7% (1 yr); 42.9% (2 yr)

BED: Biologically equivalent dose; fx: Fraction; QT: Chemotherapy.

further studies.

ES SCLC

Initial management

Chemotherapy with platinum compounds and etoposide has been the standard treatment for ES-SCLC for many decades. The COCIS meta-analysis showed that cisplatin- and carboplatin-based chemotherapy produced comparable results in terms of OS (9.6 *vs* 9.4 mo), progression free survival (PFS) (5.5 *vs* 5.3 mo), and ORR (67% *vs* 66% mo)[114]. Other strategies attempted, including maintenance treatments and combinations with antiangiogenics, have produced disappointing results[115-117]. The recently published results of the IMpower 133[118] and CASPIAN[119] trials comparing combinations of chemotherapy and immunotherapy followed by immunotherapy with standard platinum and etoposide chemotherapy in ES-SCLC have shown that the combined use of chemotherapy and immunotherapy prolongs OS.

IMpower133 is a phase III trial in which patients received four cycles of carboplatin and etoposide and either atezolizumab or placebo followed by maintenance atezolizumab[118]. The response rates in both arms were similar, but patients in the atezolizumab arm survived for a median of 2.3 mo longer [hazard ratio (HR) = 0.7; 95%CI: 0.54-0.91; *P* = 0.007]. The updated trial data presented at the 2019 European Society for Medical Oncology congress showed an increase in OS at both 12 mo (39% to 51.9%) and 18 mo (21% to 34%)[120,121].

The phase III CASPIAN trial has three treatment arms. Treatment with durvalumab plus chemotherapy (4-6 cycles of cisplatin or carboplatin plus etoposide) followed by durvalumab maintenance achieved an OS of 12.9 mo (*vs* 10.5 mo for standard chemotherapy) (HR = 0.75; 95%CI: 0.62-0.9; *P* = 0.0032), a 2-year PFS of 11% (*vs* 2.9%), and a 2-year response rate of 13.5% (*vs* 3.9%)[119, 122]. In the third arm, tremelimumab plus durvalumab *vs* chemotherapy showed no benefit in antitumor activity and was associated with increased toxicity[123].

Results from other studies evaluating combinations of anti-programmed death 1 (PD-1) antibodies have been disappointing. While the combined use of pembrolizumab and chemotherapy increased PFS, it did not provide any significant improvements in OS[124]. In the phase II ECOG-ACRIN EA5161 trial, chemotherapy plus nivolumab followed by maintenance treatment achieved a non-significant improvement in PFS (5.5 *vs* 4.7 mo) and OS (11.3 *vs* 8.5 mo)[125] (Table 3). A systematic review and two meta-analyses published in 2020 concluded that a combination of chemotherapy with atezolizumab or durvalumab was the best first-line treatment for ES-SCLC[126,127]. Other options that have been explored include combinations of ipilimumab and chemotherapy (no benefit and greater toxicity)[128, 129] and combinations of different chemotherapy agents, such as irinotecan plus etoposide and cisplatin plus irinotecan (also without benefits)[130-132].

Table 3 Combined first-line immunotherapy options for extensive-stage small cell lung cancer

Study	n	Design	Treatment	RR	PFS	OS
NCT01450761	1132	Phase III; Randomized, double-blind; Drug: Ipilimumab	Arm A: PE × 4C + ipilimumab × 4C; Control: PE × 4C + placebo × 4C	PR 62% <i>vs</i> 62%; SD 26% <i>vs</i> 27%; PD 6% <i>vs</i> 9%	4.6 <i>vs</i> 4.4 mo; HR = 0.85, <i>P</i> = 0.0161	11.0 <i>vs</i> 10.9 mo; HR = 0.94, <i>P</i> = 0.3775
Impower 133	403	Phase III. Randomized, double-blind; Drug: Atezolizumab	Arm A: PE + atezolizumab × 4C/atezolizumab; Control: PE + placebo × 4C/placebo	60% <i>vs</i> 64%	5.2 <i>vs</i> 4.3 mo; HR = 0.77, <i>P</i> = 0.02	12.3 <i>vs</i> 10.3 mo; HR = 0.70, <i>P</i> = 0.007
CASPIAN	805	Phase III. Randomized, open-label; Drug: Durvalumab	Arm B (<i>n</i> = 268): Durvalumab + PE × 4C/durvalumab; Control: PE × 4C	68% <i>vs</i> 58%	5.1 <i>vs</i> 5.4 mo; HR = 0.78, <i>P</i> not tested	13.0 <i>vs</i> 10.3 mo; HR = 0.73, <i>P</i> = 0.0047
CASPIAN	805	Phase III. Randomized, open-label; Drug: Durvalumab + tremelimumab	Arm A (<i>n</i> = 268): Durvalumab + tremelimumab + PE × 4C/durvalumab + tremelimumab. Control: PE × 4C	58% both arms	4.9 <i>vs</i> 5.4 mo; HR = 0.84	10.4 <i>vs</i> 10.5 mo; HR = 0.82, <i>P</i> = 0.045
KEYNOTE 604	453	Phase III; Randomized, double-blind; Drug: Pembrolizumab	Arm A: Pembrolizumab + PE; Control: PE + placebo	71% <i>vs</i> 62%	4.5 <i>vs</i> 4.3 mo; HR = 0.75, <i>P</i> = 0.0023	10.8 <i>vs</i> 9.7 mo; HR = 0.80, <i>P</i> = 0.0164
ECOG-ACRIN	160	Phase I. Randomized, open-label; Drug: Nivolumab	Arm A: PE + nivolumab × 4C/nivolumab; Control: PE × 4C	52.29% <i>vs</i> 47.71%	5.5 <i>vs</i> 4.6 mo; HR = 0.65, <i>P</i> = 0.012	11.3 <i>vs</i> 8.5 mo; HR = 0.67, <i>P</i> = 0.038

4C: 4 cycles; OS: Overall survival; PD: Progressive disease; PE: Platinum and etoposide; PFS: Progression free survival; PR: Partial response; RR: Response rate; SD: Stable disease.

PCI in ES-SCLC

The results of the first randomized trial to demonstrate a reduction in the risk of symptomatic BM (14.6% *vs* 40.4% at 1 year) and an improvement in OS (27.1% *vs* 13.3%) in chemotherapy responders who underwent PCI were published in 2007[133]. The results are supported by data from several meta-analyses[134-136], although as a shortcoming of the trial, pre-PCI brain imaging was not performed [133]. The results of a randomized trial conducted in Japan comparing PCI with close MRI follow-up in patients with ES-SCLC who had responded to chemotherapy and had a negative brain MRI were published in 2017. While they did not show an increase in OS (11.6 mo for PCI *vs* 13.7 mo for MRI follow-up; HR = 1.27; 95%CI: 0.96-1.68; *P* = 0.094), they did show a significant decrease in the incidence of BM[137].

A recent meta-analysis showed that PCI was only associated with prolonged OS in studies where brain imaging was not performed between chemotherapy and irradiation (HR = 0.70; 95%CI: 0.57-0.85). In other words, PCI did not offer any significant benefits when preceded by MRI or CT to test for BM (HR = 0.94; 95%CI: 0.74-1.18)[138]. Considering the above results and the neurotoxic effects of PCI[139], it would seem reasonable to consider periodic MRI examination as an alternative to PCI in patients with ES-SCLC. In such cases, a joint evaluation should be made by the medical and radiation oncologists[30]. The recommended dose for PCI is 25 Gy in 10 fractions, as higher doses do not appear to reduce the incidence of BM at 2 years and are associated with higher mortality and chronic neurotoxicity[140].

Treatment of refractory and relapsed SCLC

Relapsed SCLC tends to be resistant to treatment and is associated with an OS of 4-5 mo. Response to second-line treatment varies according to PFS and is 10% in patients with a PFS < 3 mo (refractory SCLC) and 25% in those with a PFS of 3-6 mo (sensitive SCLC)[141-143].

Relapse after PFS > 3 mo: Rechallenge treatment with combinations of platinum-based chemotherapy has been investigated in patients with sensitive SCLC. Patients treated with carboplatin and etoposide had a longer PFS than those treated with topotecan, and the greatest benefits were observed for those who relapsed after 6 mo[144,145].

Relapse after PFS of < 3 mo: Until recently, topotecan was the only drug authorized by the US and Food and Drug Administration (FDA) to treat relapsed SCLC. In the 2006 phase III trial that led to its approval, it significantly improved survival compared with best supportive care only[146]. Another phase III trial comparing topotecan and CAV (cyclophosphamide, doxorubicin, and vincristine) reported similar survival and response rates for the two treatments, but found topotecan to be associated with better symptom control and lower toxicity[147]. An additional study evaluating topotecan plus aflibercept, an antiangiogenic, reported an OS of 5 mo[148].

One recent advance in this setting is the recent approval by the FDA of lurbinectedin as a second-line treatment for SCLC. In a study of patients with SCLC without BM, lurbinectedin achieved an ORR of 35%, and a median response duration of 5.1 mo (> 6 mo in 25% of patients)[149]. The combination of

lurbinectedin and doxorubicin was investigated in two cohorts in a phase I trial and showed disease control rates of 81% and 70% and a median response duration of 4.5 and 5.2 mo[150]. These findings led to the design of the phase III ATLANTIS trial comparing lurbinectedin plus doxorubicin with topotecan and with CAV; a press release, however, announced no improvement in OS[151] (Figure 2).

Amrubicin is available for the treatment of relapsed SCLC in Japan, but it has not been approved by the FDA. A phase III trial comparing amrubicin with topotecan showed superior symptom control for topotecan but no significant differences in OS[152]. Immune checkpoint inhibitors have also been tested. The CheckMate 032 trial comparing nivolumab alone with nivolumab plus ipilimumab in recurrent SCLC reported improved ORR and OS in both treatment arms regardless of prior treatment or PD-L1 expression[153,154]. With these data, the FDA approved nivolumab for use in previously treated patients.

The phase III CheckMate 331 trial showed similar OS for nivolumab *vs* standard chemotherapy in the second-line treatment of SCLC[155]. Pembrolizumab has also been tested in SCLC. A pooled analysis of the KEYNOTE-028 (phase Ib)[156] and KEYNOTE-158 (II)[157,158] trials found an ORR of 19.3%, leading to FDA approval. Atezolizumab was also tested in a phase II trial, but the primary endpoint was not met[159]. Paclitaxel every 3 wk for 6 cycles plus pembrolizumab after the second cycle until disease progression achieved a disease control rate of 80% and a median OS of 9.2 mo[160]. Other drugs tested in the setting of relapsed SCLC are temozolomide[161,162], irinotecan[163], paclitaxel[164,165], docetaxel[166], gemcitabine[167,168], and vinorelbine[169]. Finally, a recent phase IIb study showed that belotecan was associated with better OS and disease control than topotecan in patients with sensitive SCLC[170].

Recent advances in systemic therapy

New drugs linked to targets with a role in cell proliferation have been developed. These include poly (ADP-ribose) polymerase (PARP) inhibitors, delta-like ligand 3 inhibitors (DLL3), and drugs that selectively inhibit oncogenic transcription. The expression of DNA damage response proteins [especially PARP1/checkpoint kinase 1 (CHK1)] is elevated in SCLC, and *in vitro* studies have shown an antitumor effect for PARP inhibitors[171]. Monotherapy with PARP inhibitors has also been investigated in different clinical trials, but the results have been disappointing. In an early study, talazoparib showed an ORR of 8.7%[172]. No benefit was observed for maintenance treatment with olaparib after first-line chemotherapy with cisplatin and etoposide[173] or for the addition of veliparib *vs* placebo to first-line cisplatin and etoposide, with findings showing no significant differences in PFS (6.1 *vs* 5.5 mo) or OS (10.3 *vs* 8.9 mo)[174,175].

Discordant results have been reported for combinations of chemotherapy and PARP inhibitors in successive treatment lines. No significant differences were found for PFS or OS in a study comparing temozolomide plus veliparib *vs* temozolomide only[176]. Temozolomide combined with olaparib, however, was associated with a response rate of 41.7%, a PFS of 4.2 mo, and an OS of 8.5 mo in a phase I/II clinical trial[177]. No benefits have been observed for the combined use of PARP inhibitors and immunotherapy (durvalumab with olaparib, among others)[178]. Future actions targeting this actionable molecular pathway in SCLC will probably involve combinations of PARP inhibitors and chemotherapy agents and immunotherapy, or new molecules. Promising results have been reported for CHK1 (SRA737) combined with low-dose gemcitabine and anti-PD-1/programmed death ligand 1 (PD-L1) immune checkpoint inhibitors[179] and for PARP inhibitors combined with WEE1 inhibitors, which act at the cell-cycle level[180].

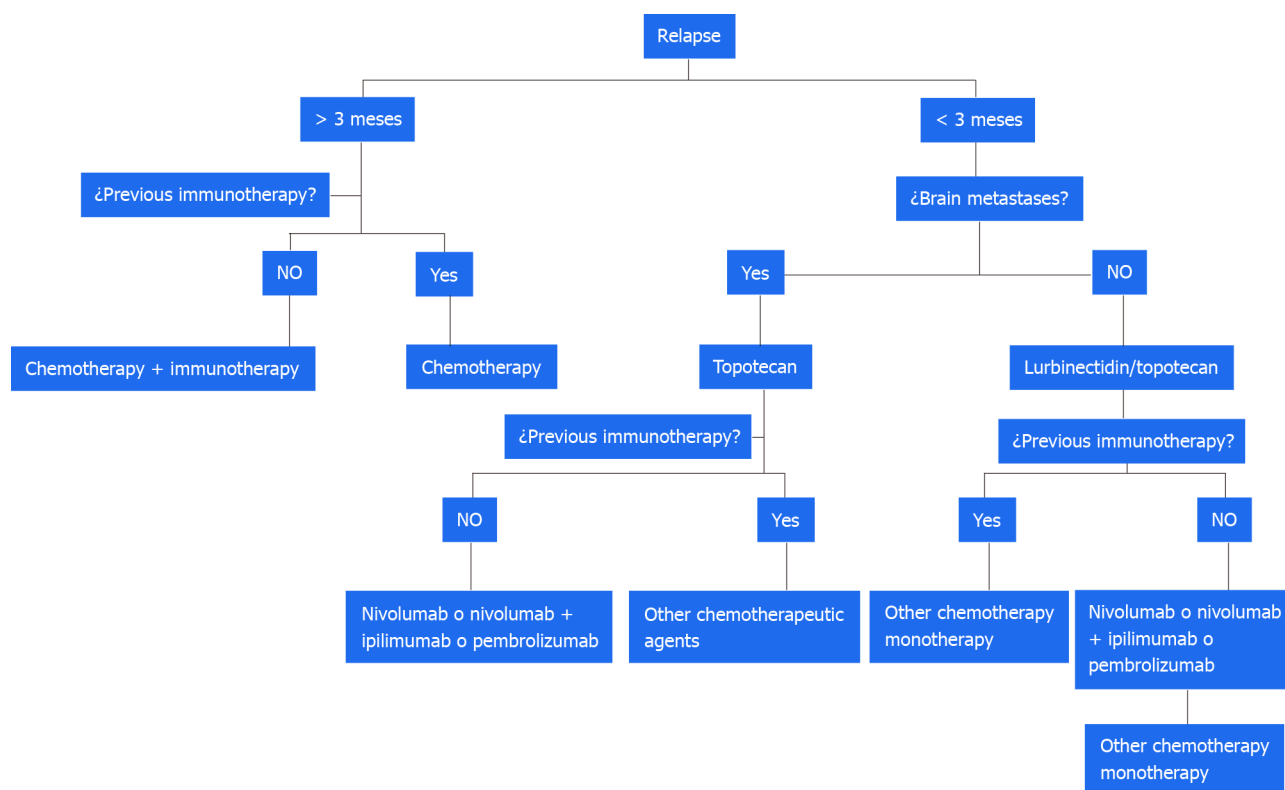
Other treatments have also yielded positive results. Lurbinectedin, a selective oncogenic transcription inhibitor, was recently evaluated in combination with irinotecan in pretreated patients in a phase Ib/II basket trial. The results for the SCLC cohort showed an ORR of 62%, a clinical benefit rate of 81%, a disease control rate of 90%, and a PFS of 6.1 mo[181]. Other new molecules with different ligands under investigation include DLL3 inhibitors, such as rovalpituzumab-tesirine. This is a promising drug in pretreated patients expressing DLL3, although recent reports have described greater toxicity and little benefit compared with topotecan[182-184]. AMG 757, a half-life extended DLL3 bispecific T-cell engager, has also shown promising results in pretreated patients in an ongoing phase I trial, with an ORR of 14%, a disease control rate of 37%, and a very promising median duration of 6.2 mo[185].

Perspectives for radiotherapy in ES-SCLC

Numerous questions remain to be answered regarding the role of radiotherapy in ES-SCLC.

Consolidation radiotherapy in extensive SCLC: What is the optimal radiation dose or indication for patients with complete thoracic response or partial distant response? The Chinese phase III trial (NCT02675088) is comparing 45 Gy at 3 Gy/d in 15 fractions *vs* 10 fractions (CREST trial schedule) with a primary endpoint of OS at 2 years[186]. How can radiotherapy be best combined with immunotherapy? The RAPTOR phase II/III trial (NCT04402788) is evaluating the use of radiotherapy to the chest and distant lesions after 4-6 cycles of carboplatin and etoposide plus atezolizumab.

Stereotactic radiosurgery to treat BM: Stereotactic radiosurgery has not traditionally been investigated in SCLC due to the high incidence of BM and poor prognosis. Nonetheless, there is growing evidence



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Figure 2 Proposed algorithm for the treatment of relapsed small cell lung cancer.

that it may be appropriate[187]. ENCEPHALON, a phase II trial (NCT03297788) is currently comparing stereotactic radiosurgery with whole-brain radiotherapy in patients with SCLC and 1-10 BM.

CONCLUSION

The treatment of SCLC will continue to be a challenge. Immunotherapy has a new role lung cancer and will be the future treatment standard alone or in combination, as well as the new radiotherapy techniques. As has been occurred in non-SCLC, the future of treatments in both early and advanced stages is through immunotherapy and targeted treatments. Furthermore, the use of different combinations of chemoimmunotherapy in recent months has improved the prognosis of patients with advanced SCLC. Nevertheless, continued research efforts are needed. Different lines of investigation are open and we hope that their findings will continue to improve prognosis and quality of life in this setting.

FOOTNOTES

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