

Immune checkpoint Blockade

NCI CCR TRACO

Stephanie L. Goff, MD

Objectives

- The basics of immunotherapy
- Mechanism of action of checkpoint blockade
- Early clinical experience and the discovery of immune related adverse events
- Checkpoint blockade in melanoma
 - Ipilimumab
 - Nivolumab
 - Pembrolizumab
- Experimental Questions

Oncology

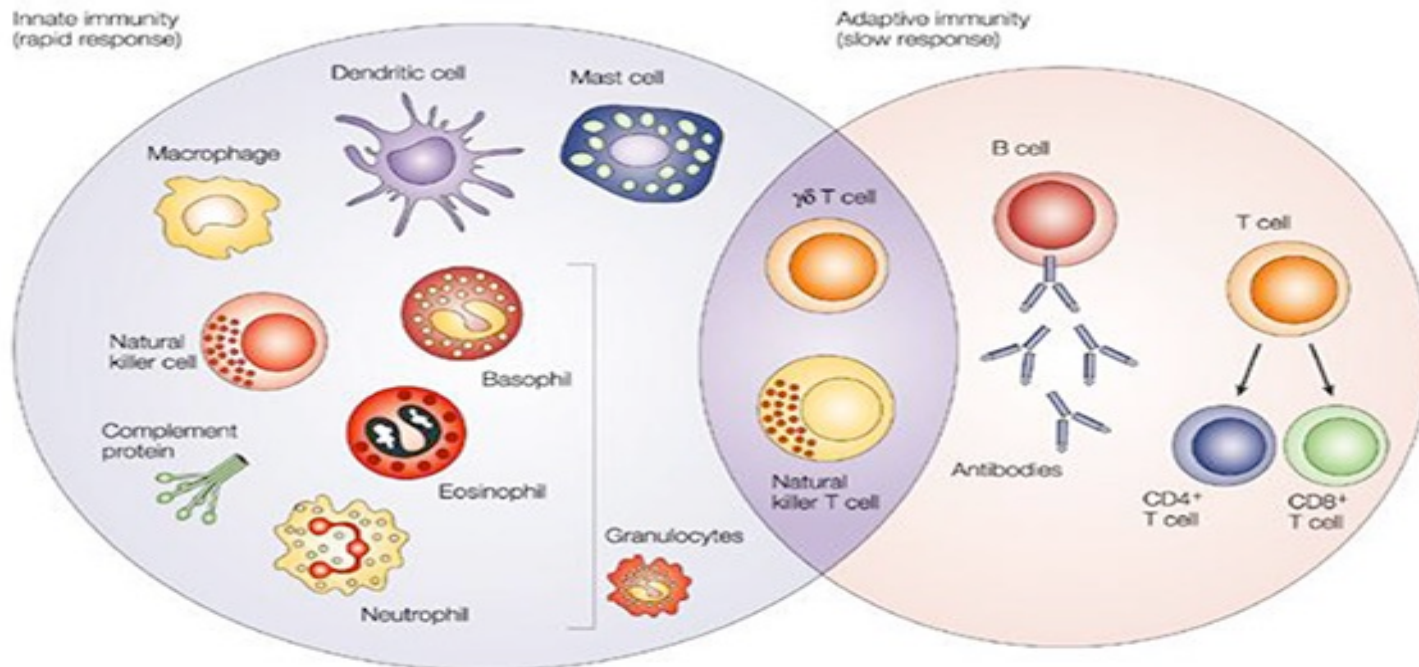


Cancer Immunotherapy

1. Nonspecific stimulation of immune reactions
 - a) Stimulate effector cells
 - b) Inhibit regulatory factors
(checkpoint blockade)
2. Active immunization to enhance anti-tumor reactions (cancer vaccines)
3. Passively transfer activated immune cells with anti-tumor activity (adoptive immunotherapy)

Immune system

Cells of the Immune System



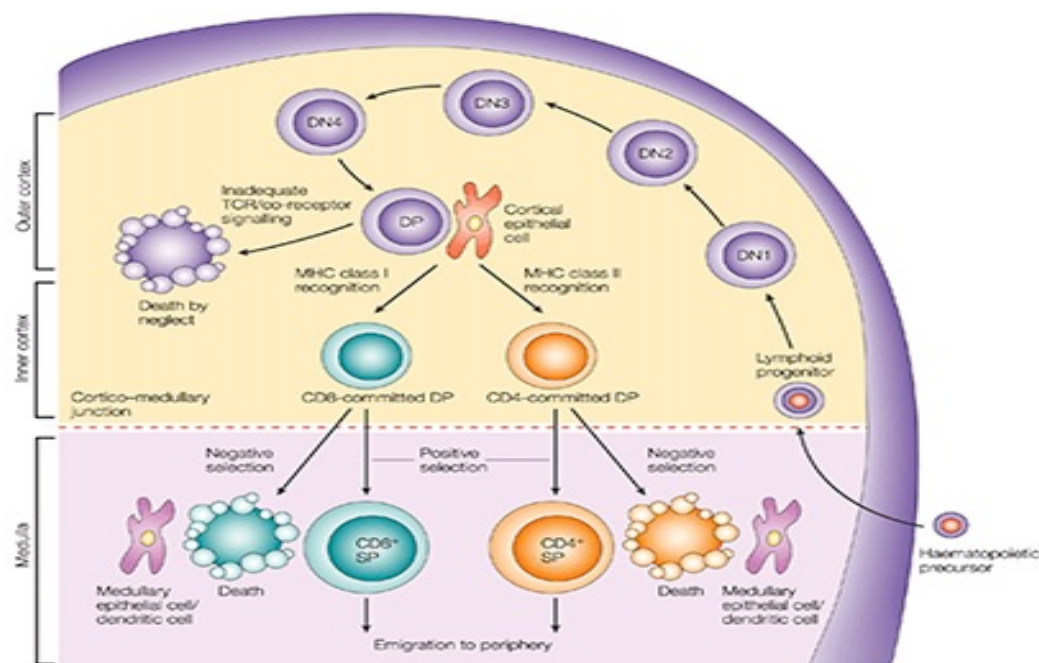
Nature Reviews | Cancer

Dranoff 2004

- Checkpoint blockade primarily affects T cells

T cell birth

T cell “birth”



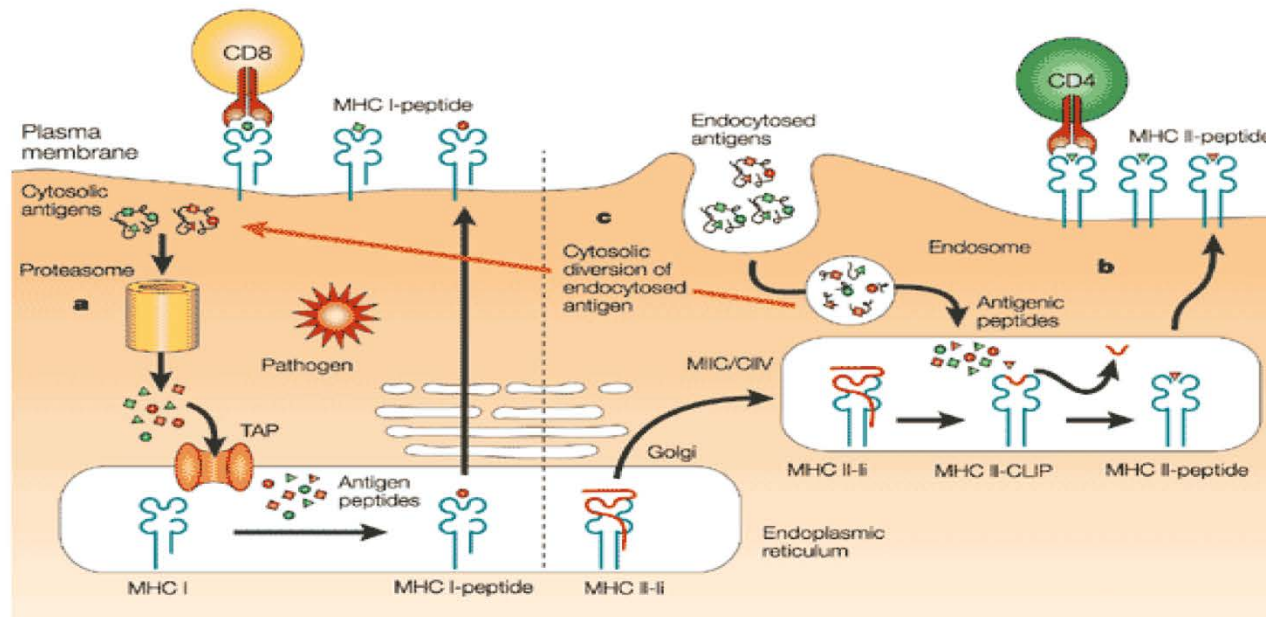
Nature Reviews | Immunology

Germain 2002

- Builds a repertoire of T cells

T cell activation

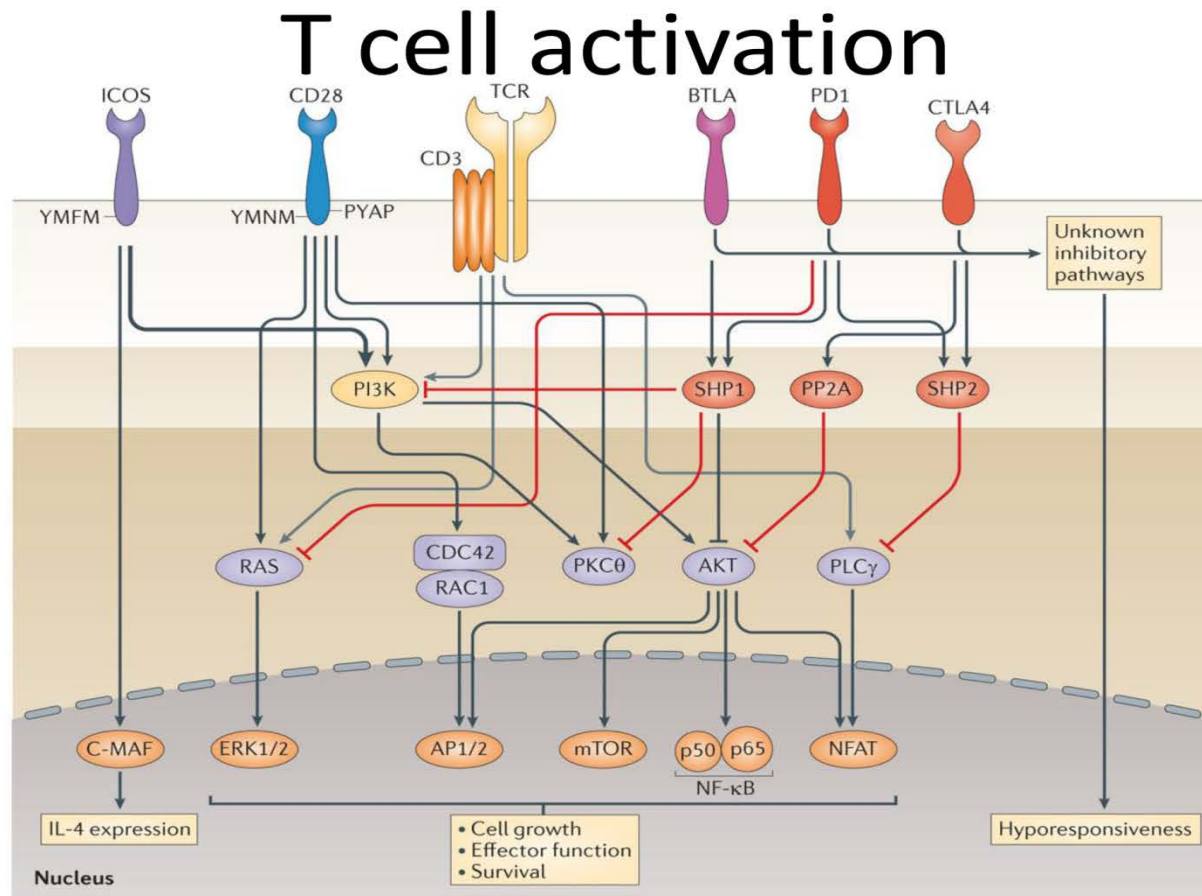
T cell activation



Nature Reviews | Immunology
Heath 2001

- Signal 1: Specificity
- TCR engages antigen in context of MHC

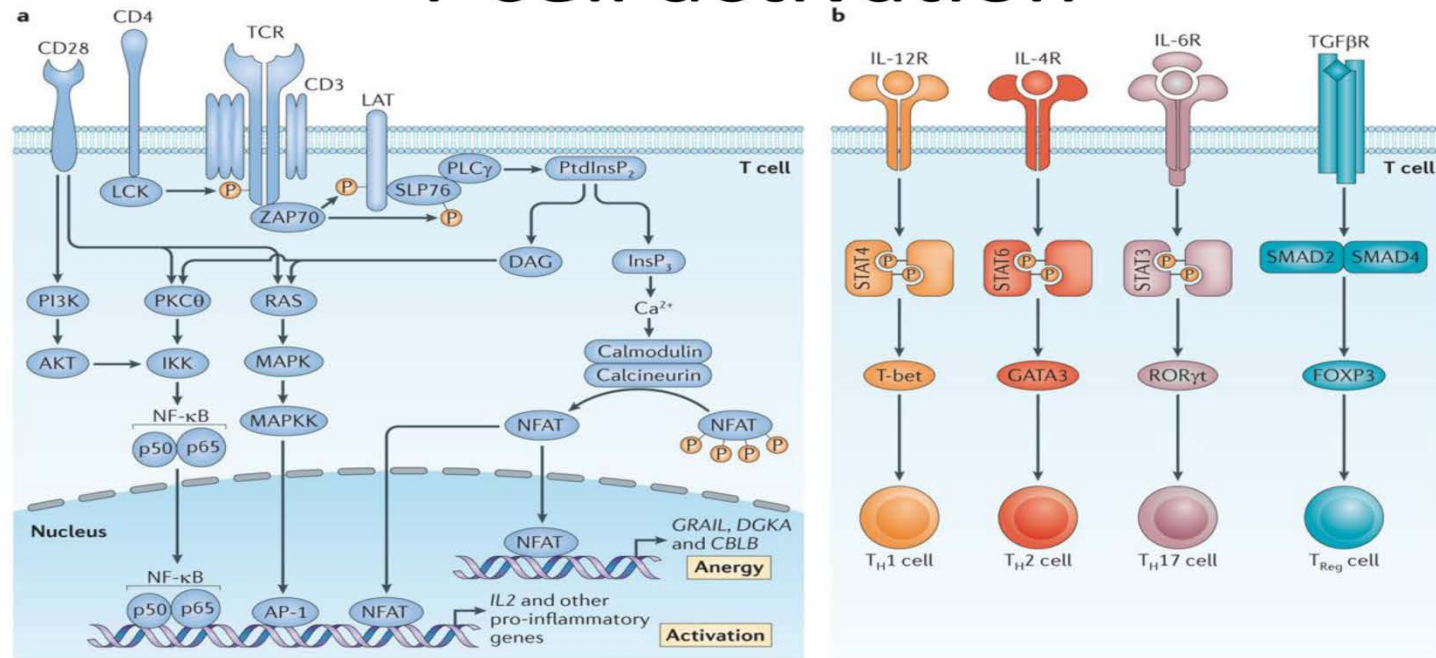
T cell activation



- Signal 2: Activation vs. Anergy

T cell activation

T cell activation



Nature Reviews | Immunology

Pollizzi 2014

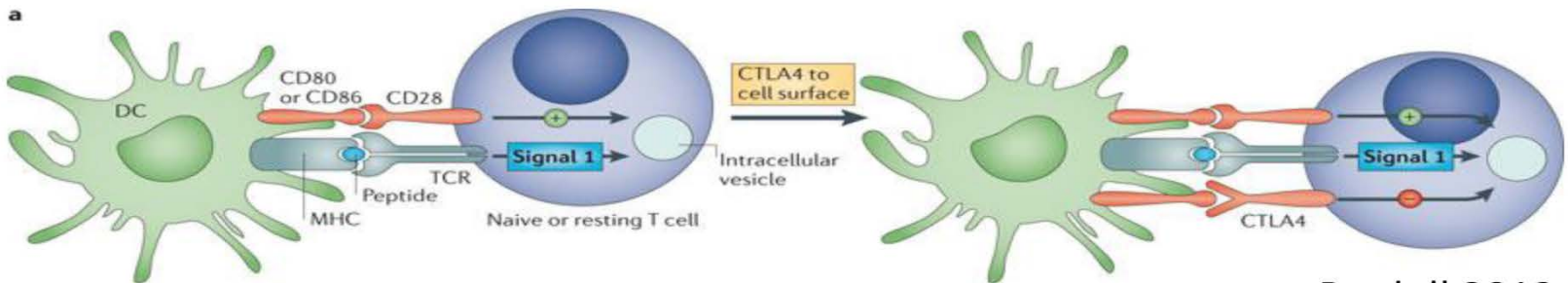
- Signal 3: Polarization
- Dependent on cytokine profile of the microenvironment

The role of Signal 2 checkpoints

- Immune checkpoints promote self-tolerance
 - Initial response to antigen occurs primarily in secondary lymphoid organs (lymph nodes, tonsils, spleen, Peyer's patches, mucosa associated lymphoid tissue)
- Immune checkpoints limit “collateral damage”
 - Effector recognition in peripheral tissue/tumor
- For cancer immunotherapy, two opportunities to break tolerance to self-antigen

CTLA-4

CTLA-4

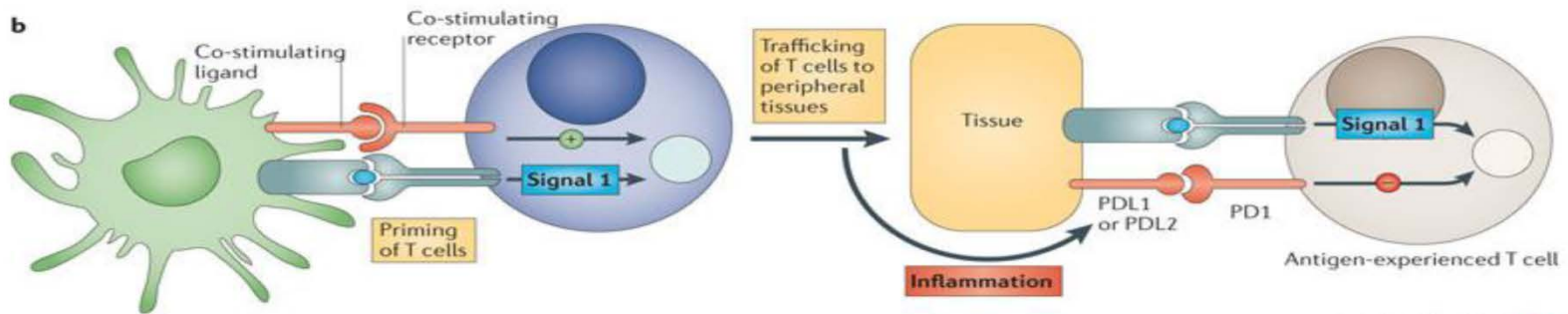


Pardoll 2012

- Naïve and memory T cells express surface CD28
- CTLA-4 is transported to the surface in correlation to the strength of CD28 stimulation
- CTLA-4 also competes with higher affinity for CD80/86
- A dampening effect on downstream processing
- Constitutively present on Treg cells

PD-1

PD-1

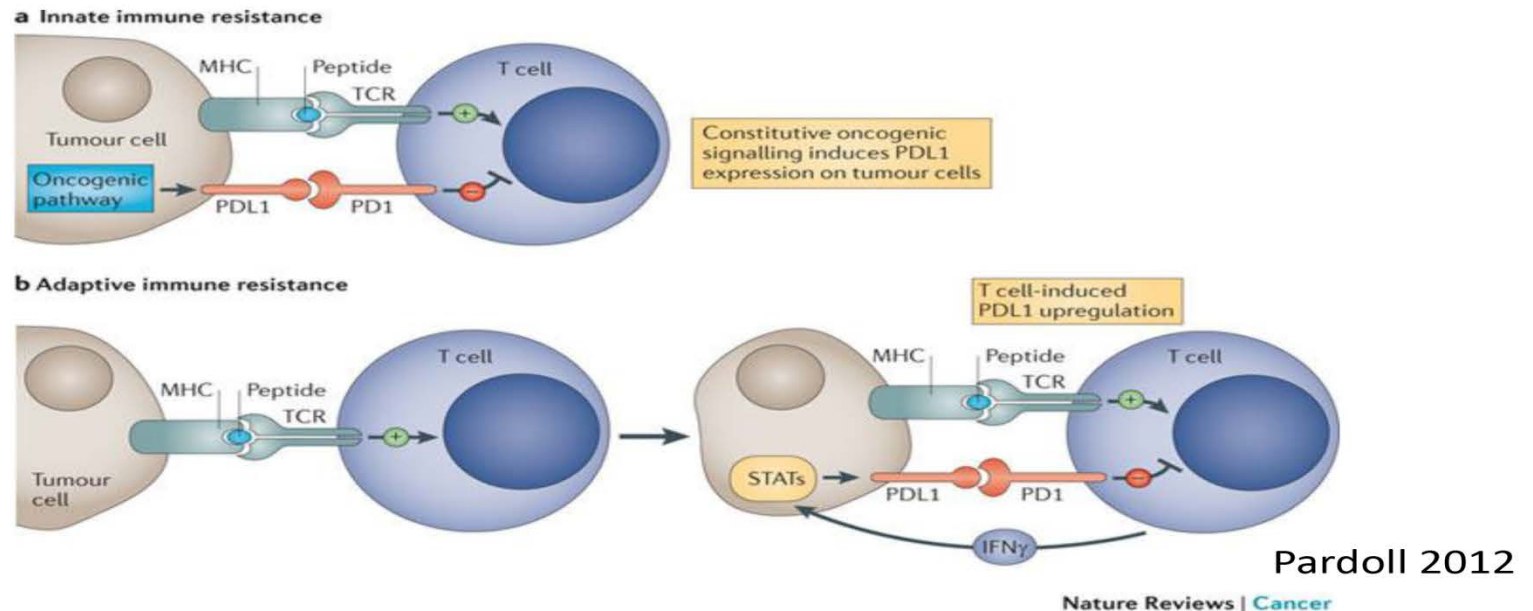


Nature Reviews | **Cancer**
Pardoll 2012

- A primed T-cell is heading to peripheral tissue to engage a target, and once activated begin to express PD-1
- Inflammation present in the tissue can promote upregulation of the ligands of PD-1
- In general, this limits collateral damage during cell-mediated destruction of infection

PD-1/PD-L1

PD-1/PD-L1 in cancer



- Cancer cells can increase the amount of PDL1
- Successful T-cell tumor destruction can increase PDL1 through upregulation in response to IFN γ

Checkpoint blockade

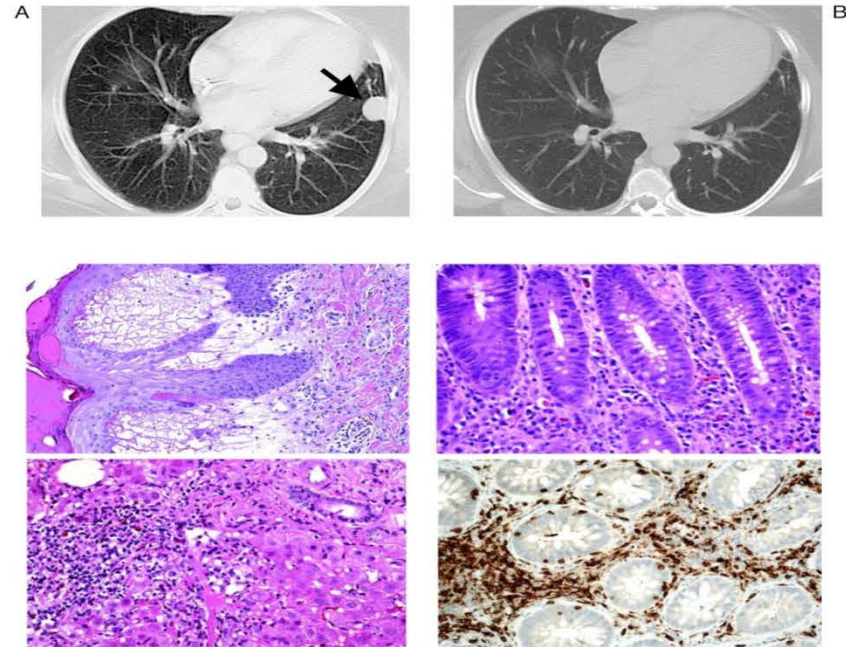
Checkpoint Blockade

- Where to start?
- Tumors known to respond to other immunotherapy
- **Melanoma**
 - Estimated 9,940 deaths/year in US
 - Metastatic disease 16% 5 yr survival
 - Interleukin-2 durable *cure* in 4%
- **Renal Cell Cancer**
 - Estimated 14,080 deaths/year in US
 - Metastatic disease 12% 5 yr survival
 - Interleukin-2 durable *cure* in 7%

Checkpoint Blockade

Checkpoint Blockade @ NCI

- α CTLA-4, ipilimumab
- Phase I trial
- mAb (3mg/kg) + peptide
- Enrolled 14 patients
- 2 complete responders
- 1 partial response
- Accrual stopped for toxicity
 - Dermatitis, colitis, hepatitis, hypophysitis



Phan GQ 2003

Checkpoint Blockade

Checkpoint Blockade @ NCI

- Cautiously proceeded with Phase II trials in melanoma and RCC, initially with dose reduction (3 → 1 mg/kg)
- Objective response was associated with development of autoimmune events

Melanoma, p=0.008

	> Gr 3 AE	< Gr 3 AE
Objective Response (CR = 2)	5 (36%)	2 (5%)
Non-responder	9	40

Attia P 2005

RCC, p=0.009

	> Gr 3 AE	< Gr 3 AE
Objective Response (CR = 0)	5 (29%)	0 (0%)
Non-responder	12	23

Yang JC 2007

Checkpoint Blockade

Checkpoint Blockade @ NCI

- Formal Phase II intra-patient dose escalation demonstrated association of response with immune-related adverse events of any grade
- Enterocolitis was the most common grade 3/4 IRAE in patients with melanoma (18%) or RCC (28%)
- The administration of steroids to manage IRAE did not truncate responses

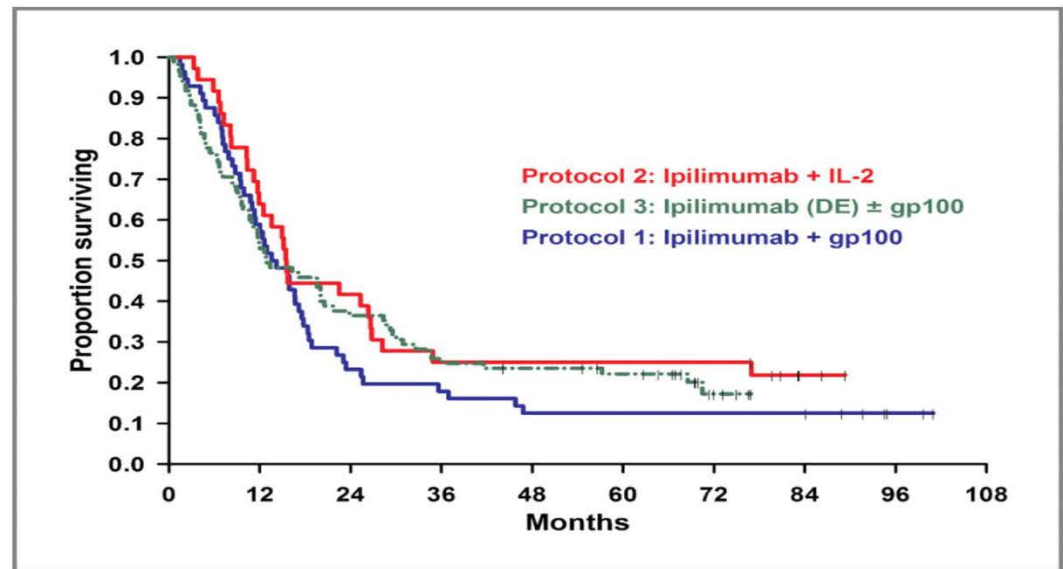
Melanoma, $p=0.0004$

	Gr 3/4 IRAE	Gr 1/2 IRAE	No IRAE
Objective Response (CR = 3)	14 (28%)	8 (22%)	1 (2%)
Non- responder	36	28	52

Checkpoint Blockade

Checkpoint Blockade @ NCI

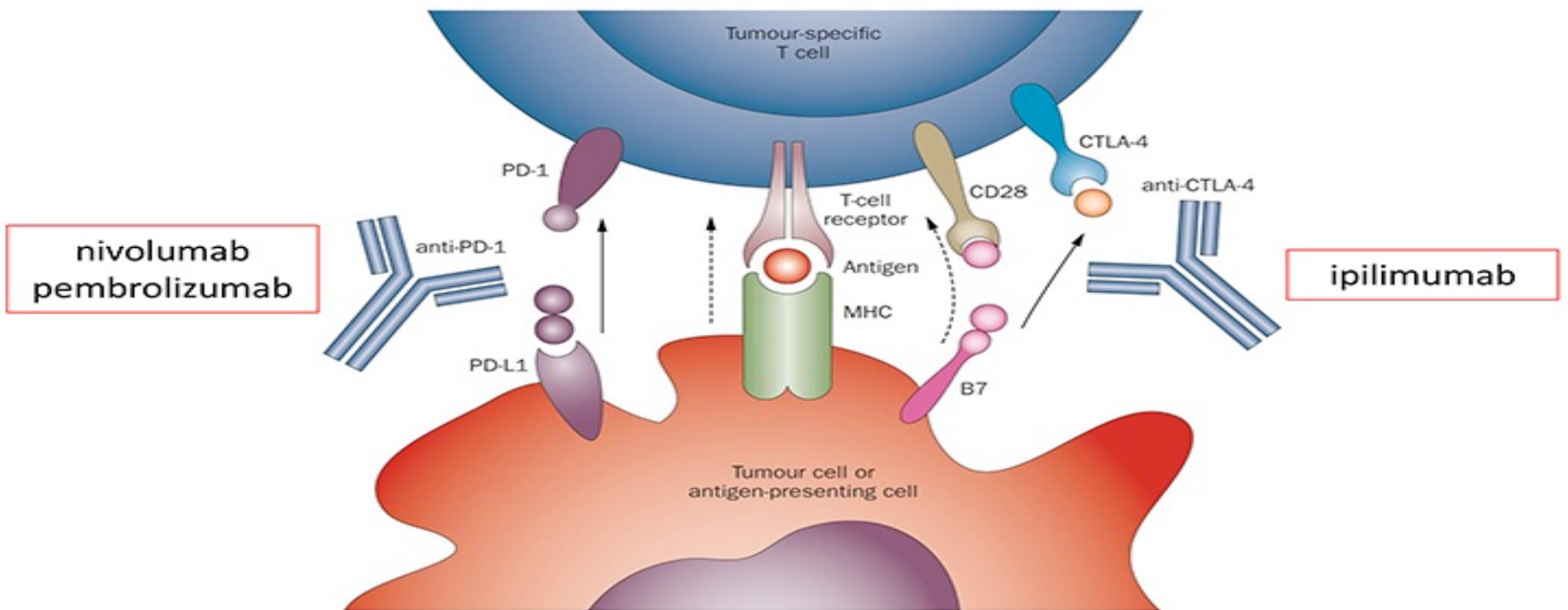
- Developed algorithms for management of IRAEs
- Demonstrated durability of responses
 - OR 13-20%
 - 5 yr OS 13-23%



Prieto PA 2012

Checkpoint blockade

Checkpoint blockade in melanoma

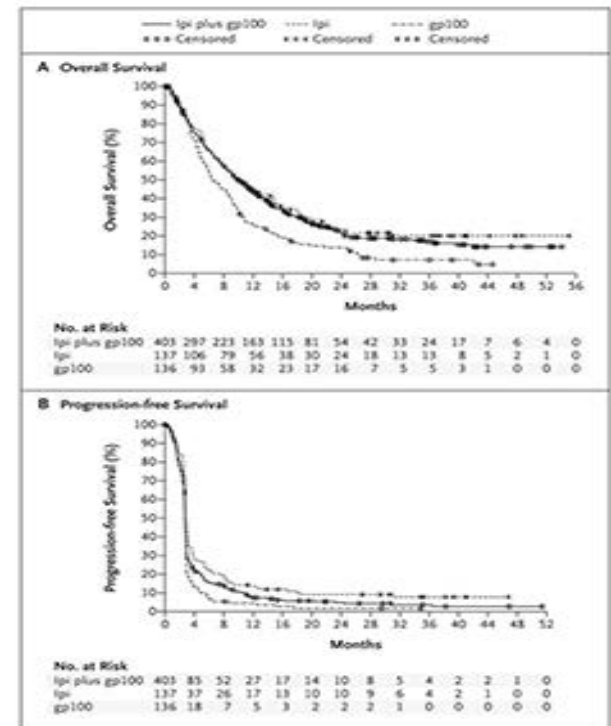


Drake C 2013

Ipilimumab

Ipilimumab for melanoma

- 11% response rate in Phase II trials at highest doses (10 mg/kg)
- Randomized Phase III ipilimumab ± gp100 vaccine vs. gp100 vaccine
- Allowed re-induction
- OR: ipilimumab arms 7% (38/540) CR in 3 patients
- Disease control rate 22%
- **FDA approved for metastatic melanoma in March 2011**



Hodi FS 2010

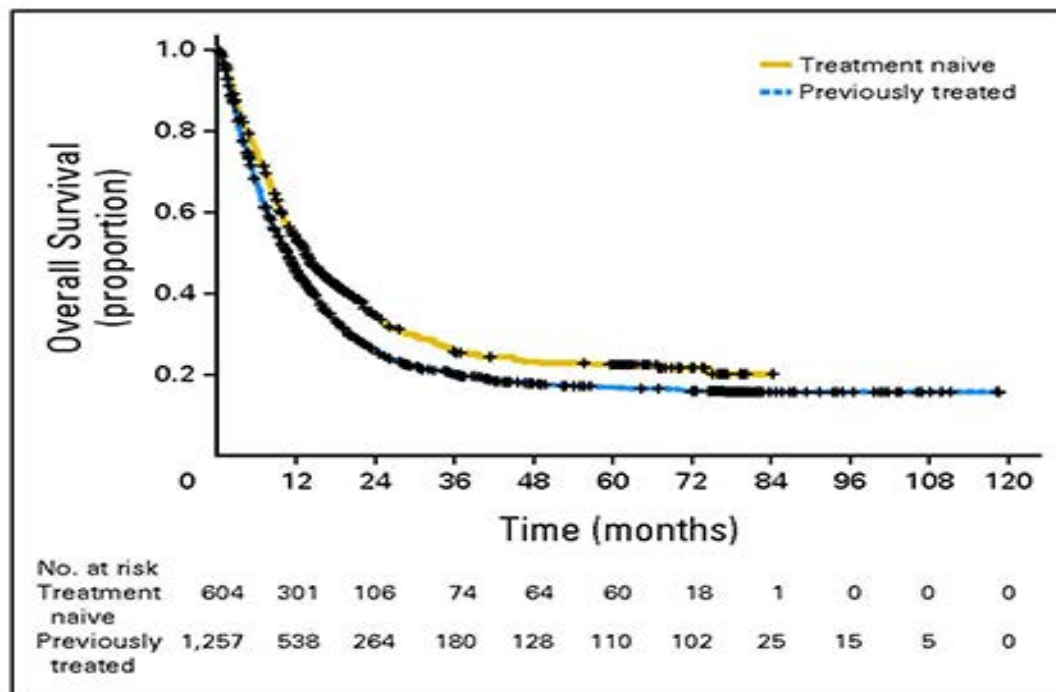


The NEW ENGLAND
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Ipilimumab

Ipilimumab for melanoma

- Updated survival
- 3 year OS, 20-26%
- “Tail of the curve”
 - Durable for a small # of patients

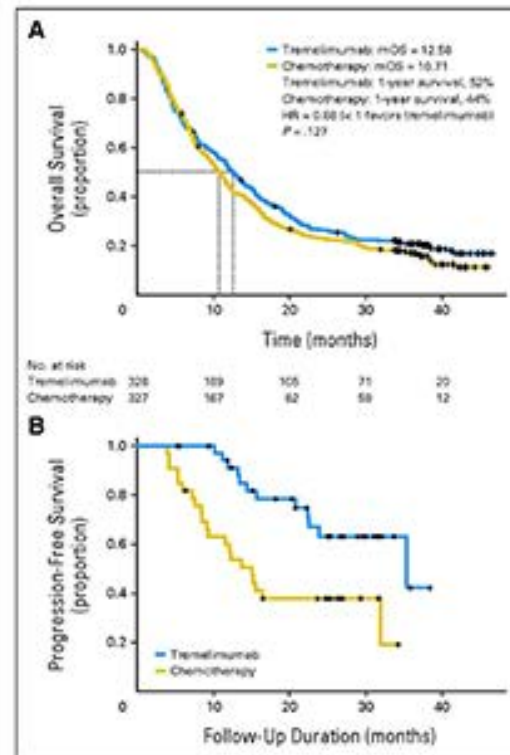


Schadendorf D 2015

Tremelimumab

Tremelimumab

- α CTLA-4
- 10% response rate in Phase II trials
- Randomized Phase III tremelimumab vs. dacarbazine/temozolomide
- No cross-over
- Failed to demonstrate survival advantage
- Currently being studied in combination trials

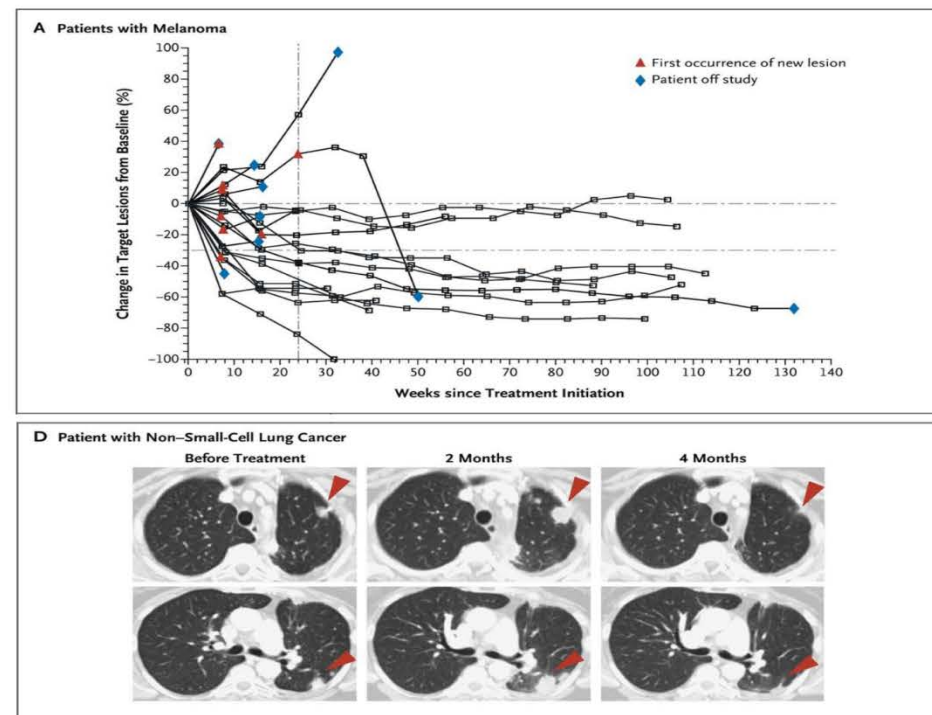


Ribas A 2013

Nivolumab

Nivolumab

- α PD-1
- Phase I dose escalation
- 0.1 mg/kg $\rightarrow$ 10 mg/kg
 - Melanoma (26/94, 28%)
 - NSCLC (14/76, 18%)
 - RCC (9/33, 27%)
 - CRPC (0/13)
 - CRC (0/19)
- Grade 3/4 toxicities in 6%

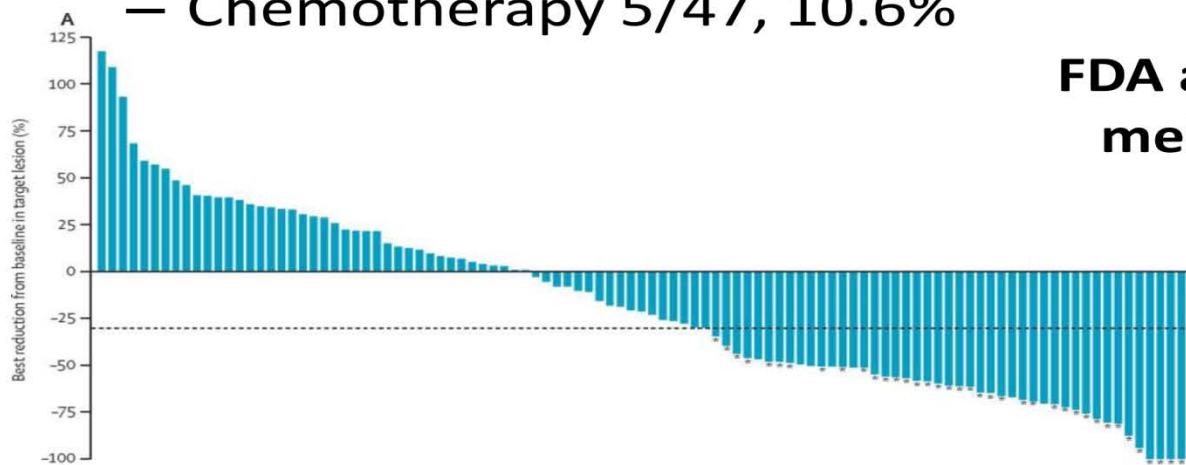


Topalian SL 2010

Nivolumab for melanoma

Nivolumab for melanoma

- Ipilimumab-refractory
- RCT: nivolumab vs chemotherapy of choice (CheckMate 037)
- Objective Response
 - Nivolumab 38/120, 31.7% with 4 CR
 - Chemotherapy 5/47, 10.6%

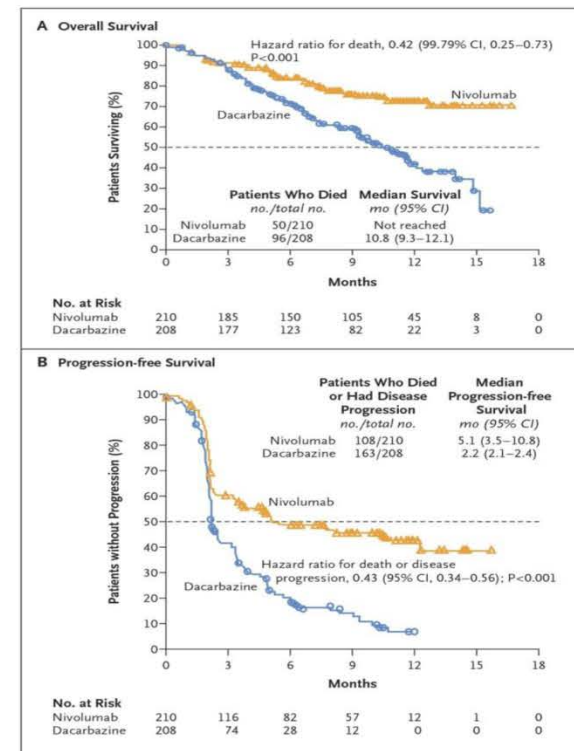


**FDA approval for refractory
melanoma in December
2014**

Nivolumab for melanoma

Nivolumab for melanoma

- Untreated metastatic disease
- Wildtype BRAF
- RCT: nivolumab vs dacarbazine (CheckMate 066)
- Objective response
 - Nivolumab 84/210 (40%)
CR in 16 pts (7.6%)
 - Dacarbazine 29/208 (14%)
CR in 2 pts (1%)



Robert C 2015



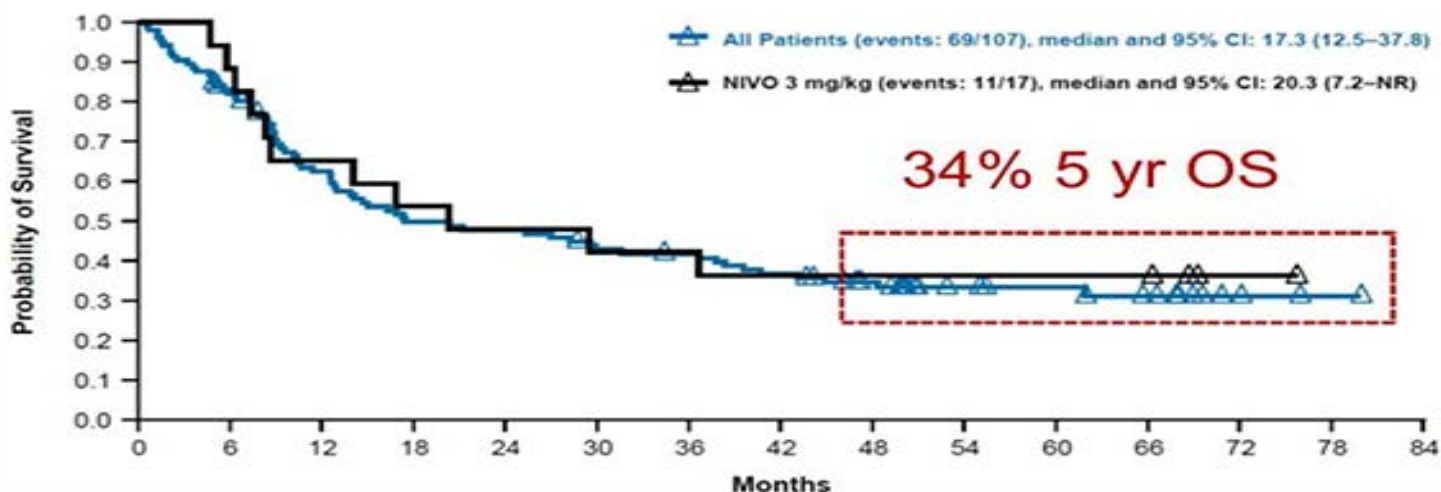
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Nivolumab for melanoma

Nivolumab for melanoma

- Updated survival
- “Tail of the curve”

Overall Survival at 5 Years of Follow-up



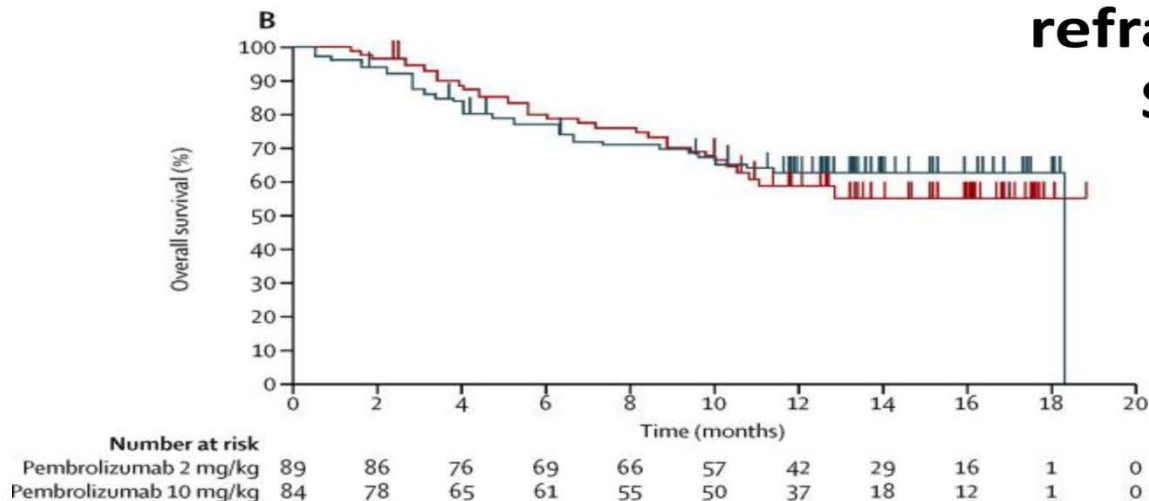
Hodi F
(presented at AACR 2016)

Pembrolizumab for melanoma

Pembrolizumab for melanoma

- Ipilimumab-refractory
- Phase I, dose comparison (2mg/kg vs 10 mg/kg)
- 157 evaluable patients with OR 41 (26%), CR in 2 pts
- Disease control rate 50%
- Grade 3/4 AE 12%

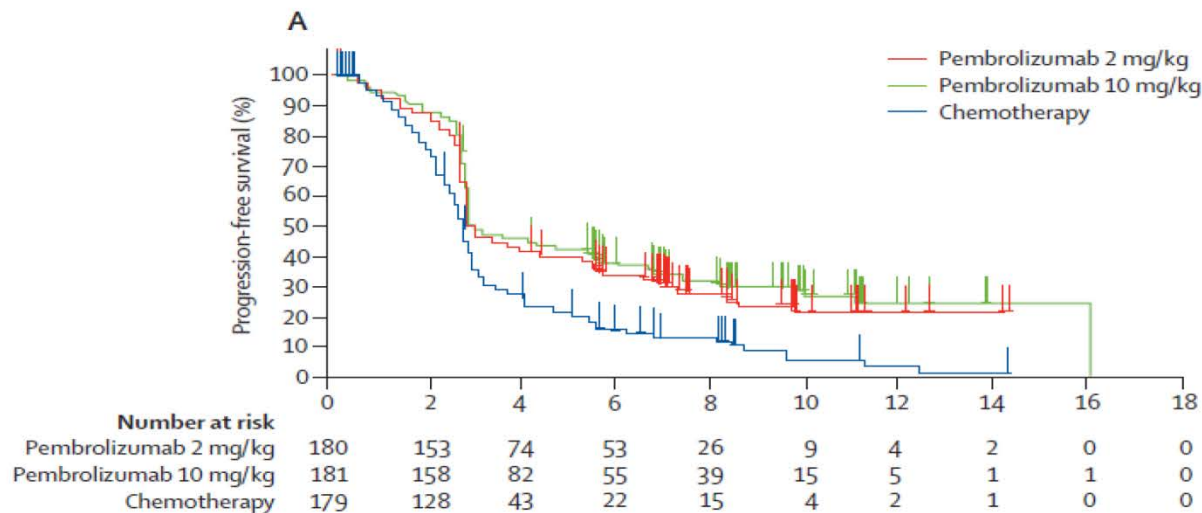
**FDA approval for
refractory melanoma in
September 2014**



Pembrolizumab for melanoma

Pembrolizumab for melanoma

- Ipilimumab-refractory
- Phase II, dose comparison (2mg/kg vs 10 mg/kg) vs chemo
- 540 patients
 - 2mg/kg ORR 38 (21%), 10 mg/kg ORR 46 (25%), chemo 8 (4%)
- Grade 3/4 AE 12%



Weber JS 2015

THE LANCET **Oncology**

Pembrolizumab for melanoma

Pembrolizumab for melanoma

- RCT, KEYNOTE-006, first-line therapy
- Pembrolizumab (q2w, q3w) vs ipilimumab
- 1:1:1
- 834 patients
- Objective Response
 - Pembrolizumab q2w 94/279 (33.7%), CR 14
 - Pembrolizumab q3w 91/277 (32.9%), CR 17
 - Ipilimumab 33/278 (11.9%), CR 4

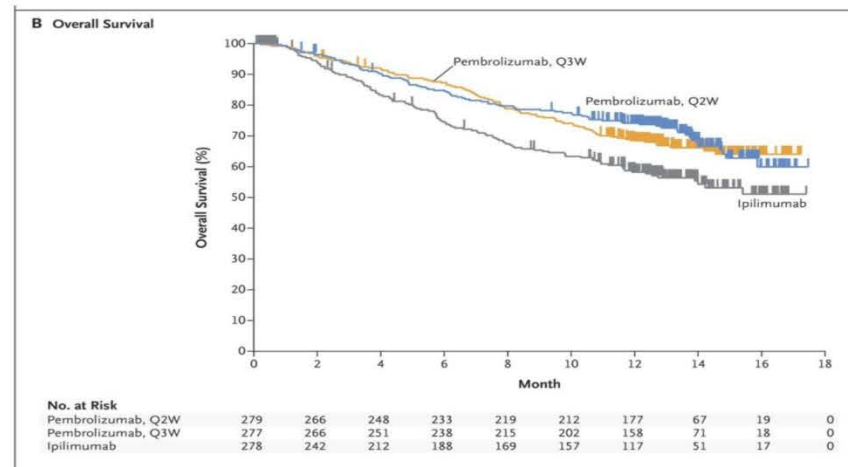
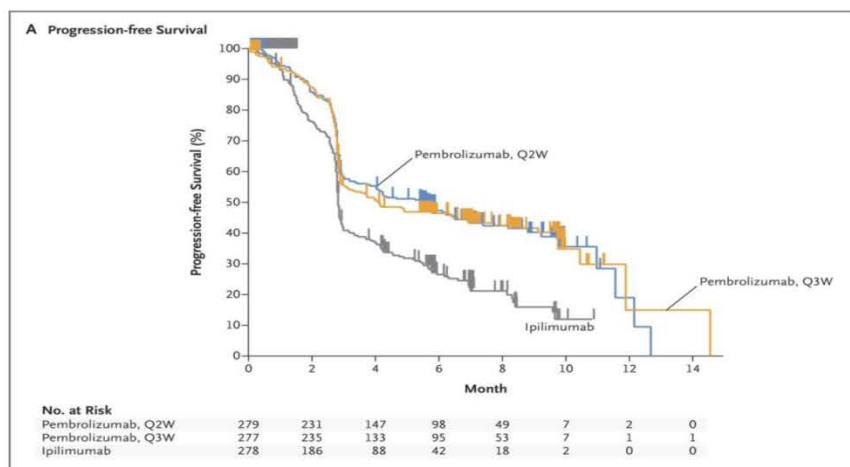
Robert C 2015



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Pembrolizumab for melanoma

Pembrolizumab for melanoma



- Grade ≥ 3 AE
 - Pembrolizumab q2w 13.3% (1.4% Colitis)
 - Pembrolizumab q3w 10.1% (2.5% Colitis)
 - Ipilimumab 19.9% (7% Colitis)

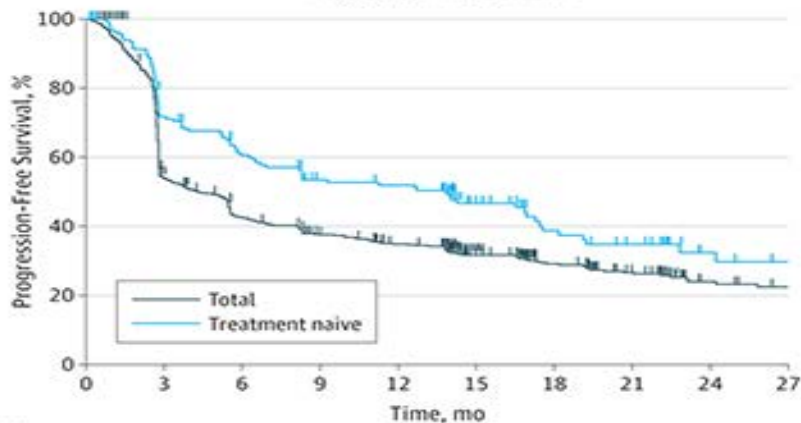
Robert C 2015

Pembrolizumab for melanoma

Pembrolizumab for melanoma

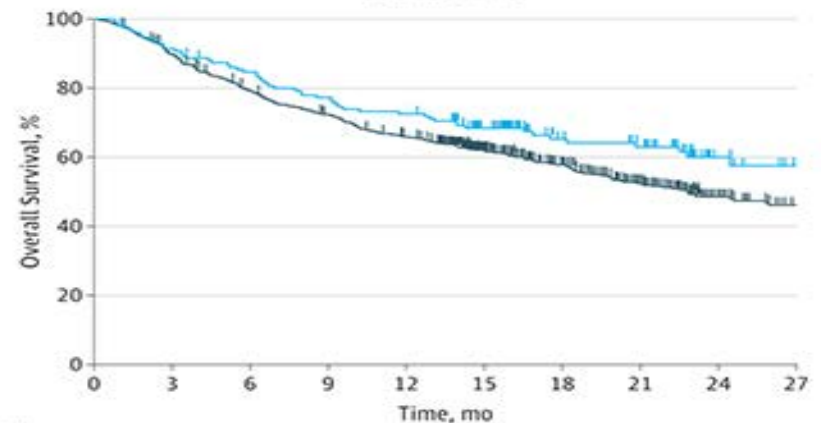
- Updated survival
- “Tail of the curve”

Progression-free survival



No. at risk										
Treatment naive	152	106	86	71	68	44	29	22	12	9
Total	655	343	264	226	201	134	99	72	35	29

Overall survival



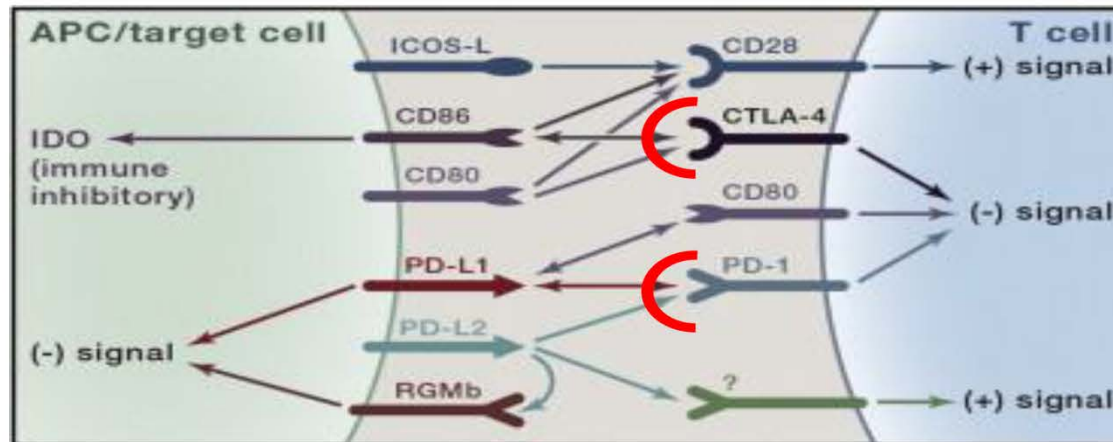
No. at risk										
Treatment naive	152	138	126	115	108	86	58	53	26	18
Total	655	584	510	461	416	318	231	174	93	66

Ribas A 2016

JAMA
The Journal of the American Medical Association

Checkpoint modulation

Checkpoint Modulation



Topalian, Cancer Cell 2015

- In melanoma, the two approved antibodies interfere with separate receptor/ligand complexes
- Could combination therapy improve response or survival?

Nivolumab/Ipilimumab

Nivolumab/Ipilimumab for melanoma

- Previously untreated
- Phase III, RCT
- 945 patients
- 1:1:1
- PD-L1 (+) $\geq 5\%$

Table 1. Characteristics of the Patients at Baseline.*				
Characteristic	Nivolumab (N = 316)	Nivolumab plus Ipilimumab (N = 314)	Ipilimumab (N = 315)	Total (N = 945)
PD-L1 status — no. (%)				
Positive	80 (25.3)	68 (21.7)	75 (23.8)	223 (23.6)
Negative	208 (65.8)	210 (66.9)	202 (64.1)	620 (65.6)
Could not be determined or evaluated	28 (8.9)	36 (11.5)	38 (12.1)	102 (10.8)
BRAF status — no. (%)				
Mutation	100 (31.6)	101 (32.2)	97 (30.8)	298 (31.5)
No mutation	216 (68.4)	213 (67.8)	218 (69.2)	647 (68.5)

Larkin J 2015



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Nivolumab/Ipilimumab

Nivolumab/Ipilimumab for melanoma

- Previously untreated
- Phase III, RCT
- 945 patients
- 1:1:1
- Grade 3/4 AE
 - Nivolumab 16.3%
 - Ipilimumab 27.3%
 - Combo 55.0%

Table 2. Response to Treatment.

Variable	Nivolumab (N = 316)	Nivolumab plus Ipilimumab (N = 314)	Ipilimumab (N = 315)
Best overall response — no. (%) [*]			
Complete response	28 (8.9)	36 (11.5)	7 (2.2)
Partial response	110 (34.8)	145 (46.2)	53 (16.8)
Stable disease	34 (10.8)	41 (13.1)	69 (21.9)
Progressive disease	119 (37.7)	71 (22.6)	154 (48.9)
Could not be determined	25 (7.9)	21 (6.7)	32 (10.2)
Objective response [†]			
No. of patients with response	138	181	60
% of patients (95% CI)	43.7 (38.1–49.3)	57.6 (52.0–63.2)	19.0 (14.9–23.8)
Estimated odds ratio (95% CI) [‡]	5.40 (2.02–5.72)	6.11 (5.59–10.58)	—
Two-sided P value	<0.001	<0.001	—
Time to objective response — mo			
Median	2.78	2.76	2.79
Range	2.3–12.5	1.1–11.6	2.5–12.4

^{*} The best overall response was assessed by the investigator according to the Response Evaluation Criteria in Solid Tumors, version 1.1.

[†] Data included patients with a complete response and those with a partial response. The calculation of the confidence interval was based on the Clopper–Pearson method. These analyses were conducted with the use of a two-sided Cochran–Mantel–Haenszel test stratified according to PD-L1 status, *BRAF* mutation status, and metastasis stage.

[‡] The comparison is with the ipilimumab group.

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Nivolumab/Ipilimumab

Nivolumab/Ipilimumab for melanoma

	Nivolumab	Nivolumab + Ipilimumab	Ipilimumab	Total
Overall ORR	43.7%	57.6%	19.0%	40.1%
PD-L1 (+)	46/80 57.5%	49/68 72.1%	16/75 21.3%	111/223 49.8%
PD-L1 (-)	86/208 41.3%	115/210 54.8%	36/202 17.8%	237/620 38.2%
PD-L1 unknown	6/28 21.4%	17/36 47.2%	8/38 21.1%	31/102 30.3%

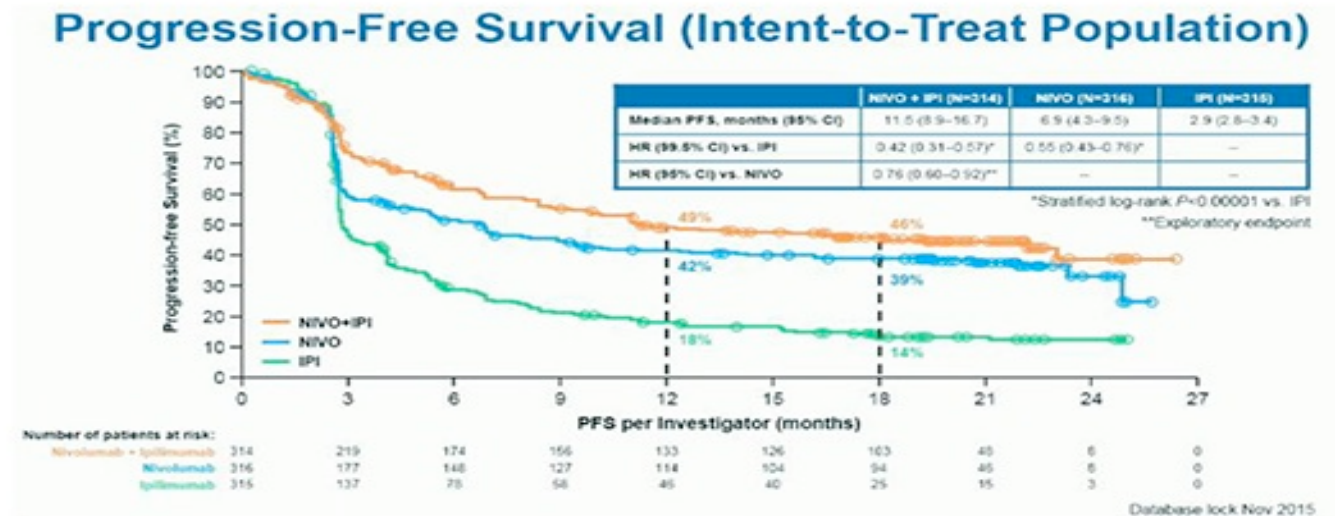
Larkin J 2015



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Nivolumab/ipilimumab

Nivolumab/Ipilimumab for melanoma -updated results-



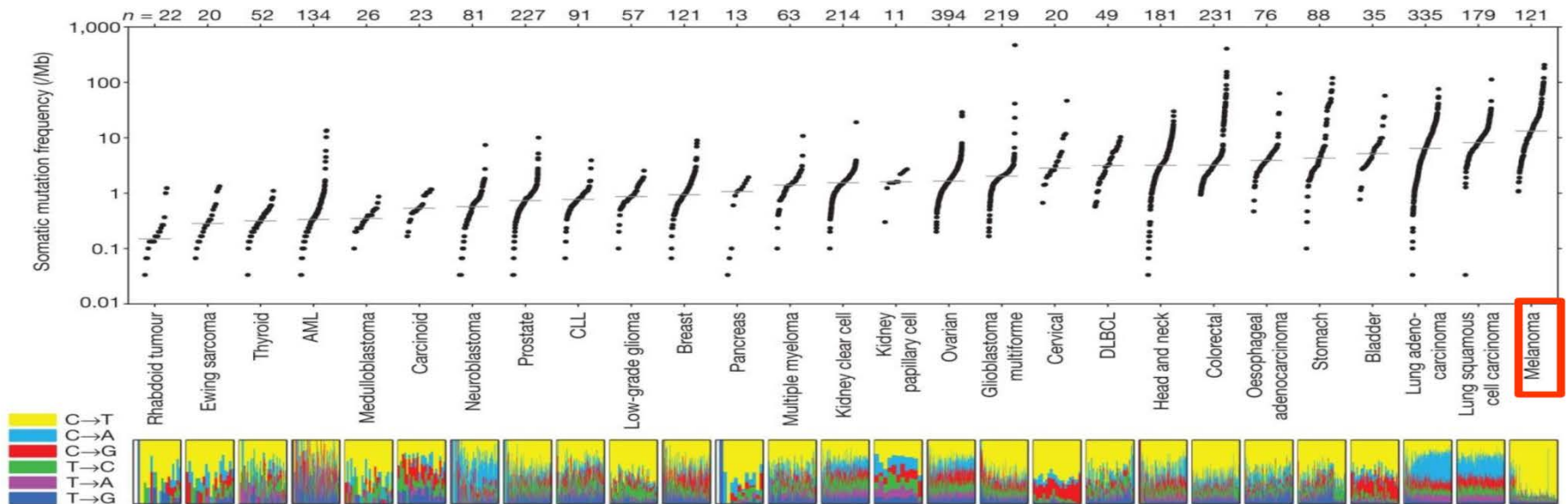
- Minimum follow-up of 18 months
- Overall survival not updated, still immature

**FDA approval of
combination for melanoma
in January 2016**

Wolchok
(presented at ASCO 2016)

Melanoma

Why melanoma?



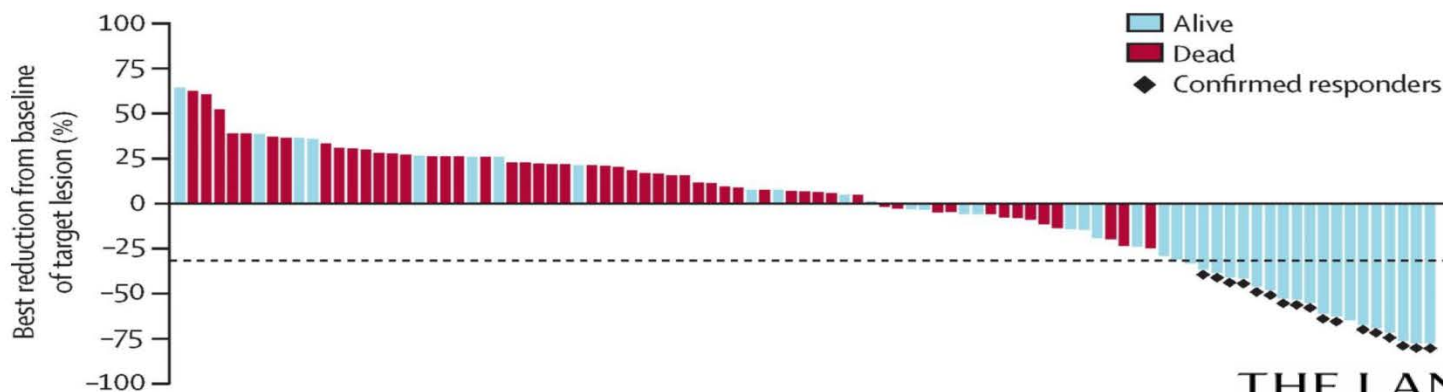
Highly mutated tumors

- Non-small cell lung cancer
- ~158,040 deaths/year in US
- Regional disease
16% 5 yr survival
- Metastatic disease
2% 5 yr survival
- Correlation between smoking and # mutations
- Tumors with mismatch repair (MMR) deficiency
 - Lynch syndrome (germline mutation)
 - Sporadic mutation
 - MSH2, MLH1, MSH6, PMS2
- Bladder cancer
 - 16,000 deaths/year in US
 - Highly lethal once metastatic

Nivolumab for NSCLC

Nivolumab for NSCLC

- NSCLC refractory to ≥ 2 treatments
- Phase II (CheckMate 063)
- 3 mg/kg q2w until progression or toxicity
- 117 patients treated
- Objective Response 17 (14.5%), no CR



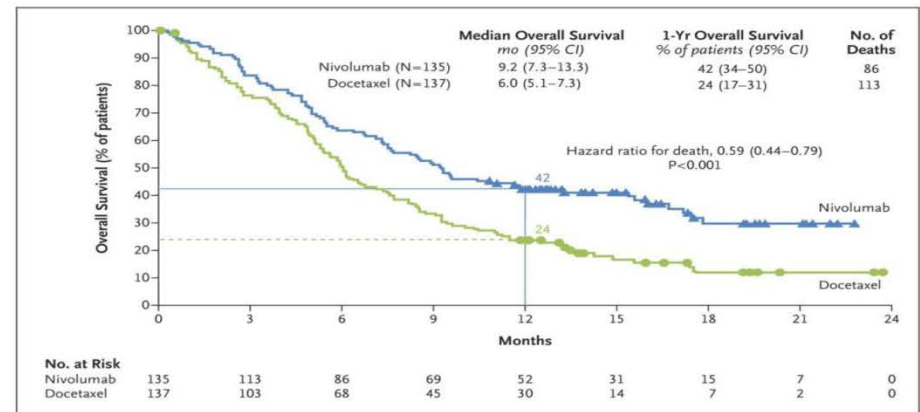
Rizvi NA 2015

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Nivolumab for NSCLC

Nivolumab for NSCLC

- RCT
- Nivolumab vs docetaxel
- Refractory to one platinum-based regimen
- Objective Response
 - Nivolumab 27/135 (20%)
 - Docetaxel 12/137 (9%)



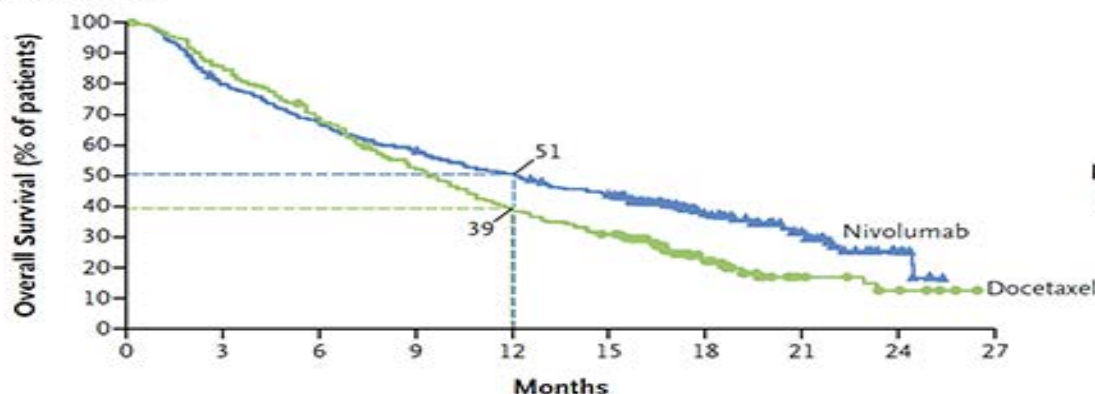
**FDA approval for
refractory NSCLC in
March 2015**

Brahmer 2015

Nivolumab for NSCLC

Nivolumab for NSCLC

A Overall Survival



	No. of Deaths/ Total No. of Patients	Median Overall Survival (95% CI) mo	1-Yr Overall Survival Rate (95% CI) %
Nivolumab	190/292	12.2 (9.7–15.0)	51 (45–56)
Docetaxel	223/290	9.4 (8.1–10.7)	39 (33–45)

Hazard ratio for death, 0.73 (96% CI, 0.59–0.89)
P=0.002

No. at Risk

Nivolumab	292	232	194	169	146	123	62	32	9	0
Docetaxel	290	244	194	150	111	88	34	10	5	0

- Nivolumab vs docetaxel
- Objective Response
 - Nivolumab 56/292 (19%)
 - Docetaxel 36/290 (12%)

**FDA approval for
refractory non-squamous
NSCLC in October 2015**

Borghaei 2015

Pembrolizumab for NSCLC

Pembrolizumab for NSCLC

- 495 patients, subset of KEYNOTE 001
- Wide range of inclusion criteria
 - 94 treatment naïve patients
 - 126 never smokers
 - 401 nonsquamous
- Majority at 10 mg/kg either q2w or q3w
- Objective response 96/495 (19.4%)
 - Never smokers 13/126 (10.3%)
 - Former/current 83/369 (22.5%)
- Grade ≥ 3 AE
 - Dyspnea 3.8%
 - Pneumonitis 1.8% including a fatality

**FDA decision to
be made
October 2, 2015**

Garon EB 2015

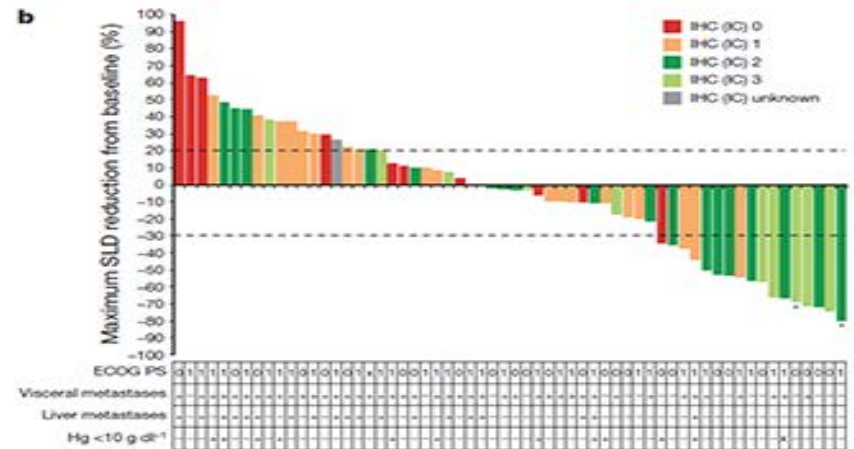


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antiPD-L1

α PD-L1 in Urothelial bladder cancer

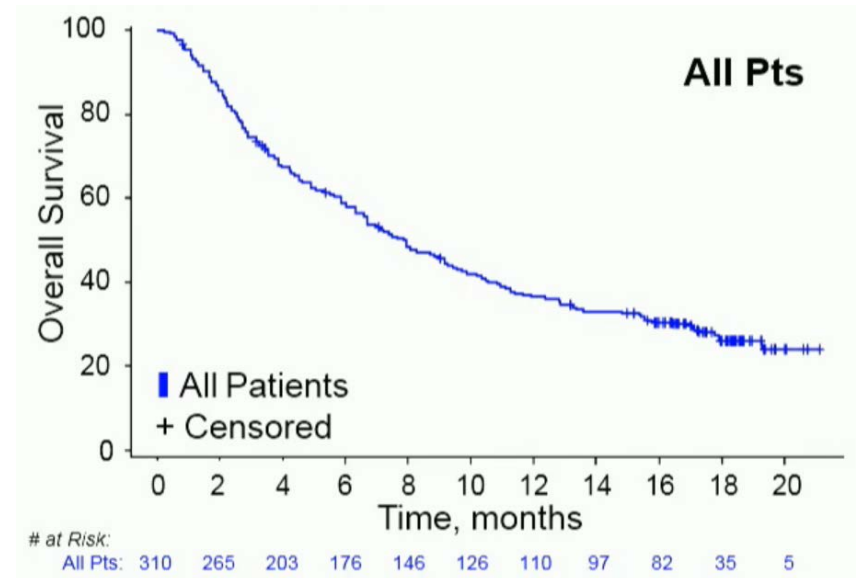
- MPDL3280A
- Atezolizumab
- 15 mg/kg q3w
- 27% tumors with >5% PD-L1 by IHC
- 65 patients with pre-treatment biopsy
- Objective Response
 - $\geq 5\%$ PD-L1 13/30 (43.3%)
 - $< 5\%$ PD-L1 4/35 (11.4%)
- Grade 3/4 AE 4%



**FDA approval for
urothelial cancer in
May 2016**

α PD-L1 in Urothelial bladder cancer

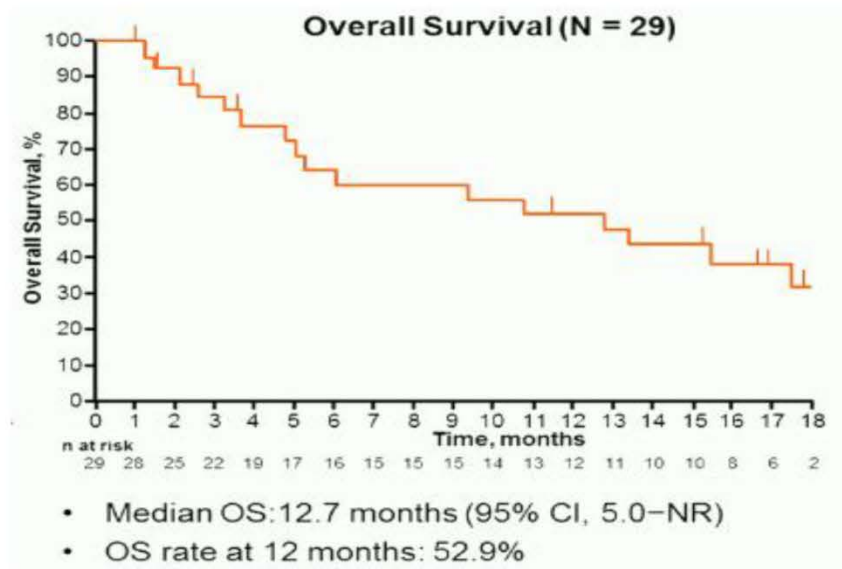
- 310 patients
- Objective Response
 - 45 (15%)
 - With 15 complete responses
- Overall Survival
 - 7.9 months
- 1 yr Survival
 - 37%



Urothelial Cancer

Pembrolizumab in Urothelial Cancer

- Part of KEYNOTE-012
- Required $\geq 1\%$ PD-L1 staining (61/95, 64.2%)
- 10 mg/kg q2w
- 33 patients (29 eval)
- OR 27.6%,
CR 10.3% (3 pts)
- Grade ≥ 3 AE 15%

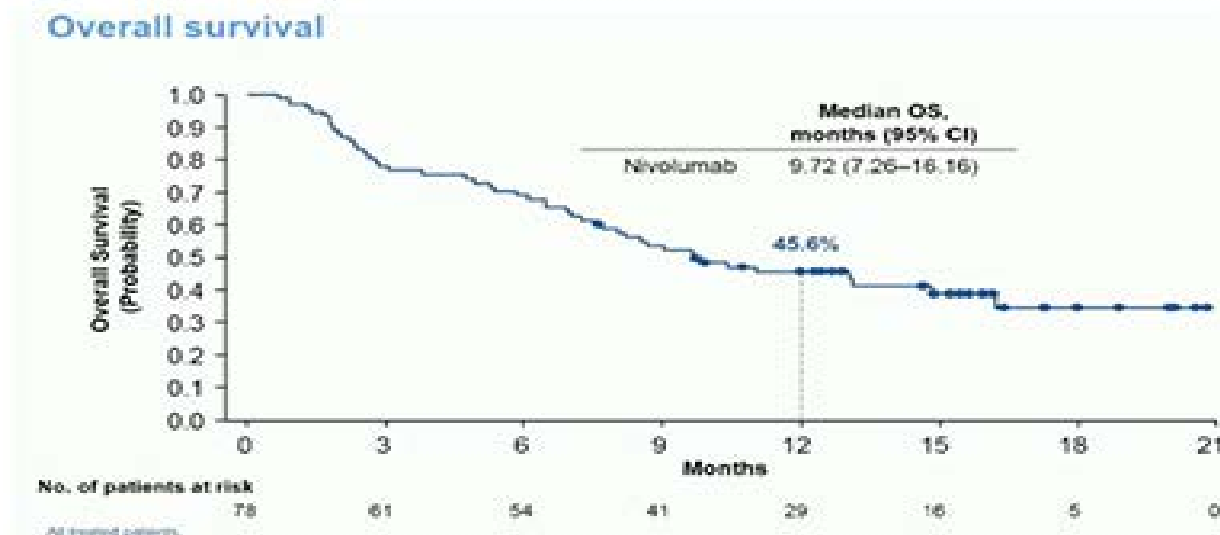


Abstract: Plimack E 2015

Nivolumab in Urothelial Cancer

Nivolumab in Urothelial Cancer

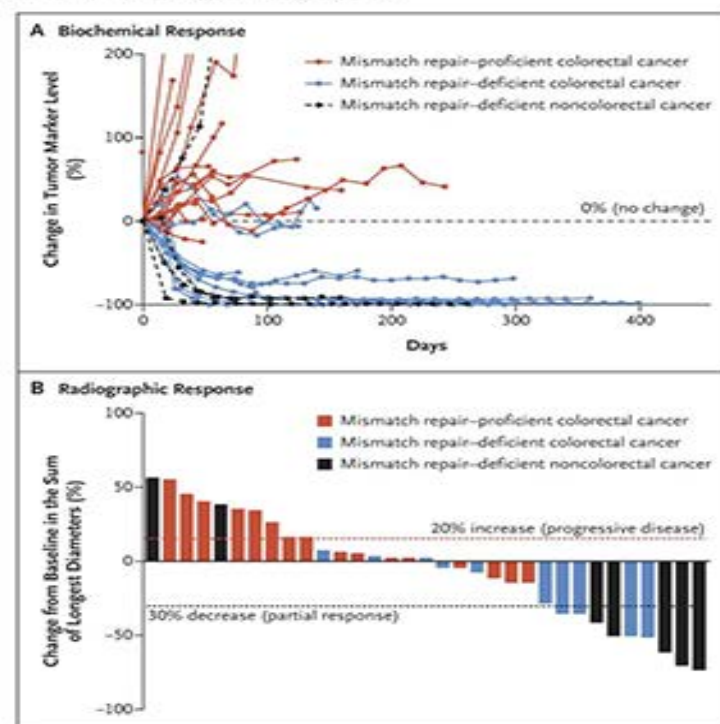
- One cohort of a larger study, 3 mg/kg q2w
- Did not require $\geq 1\%$ PD-L1 staining (25/67, 37%)
- 78 patients (29 eval)
- OR 24.4%, CR 6.4% (5 pts), Grade ≥ 3 AE 22%



MMR-deficient cancer

Pembrolizumab for MMR-deficient cancer

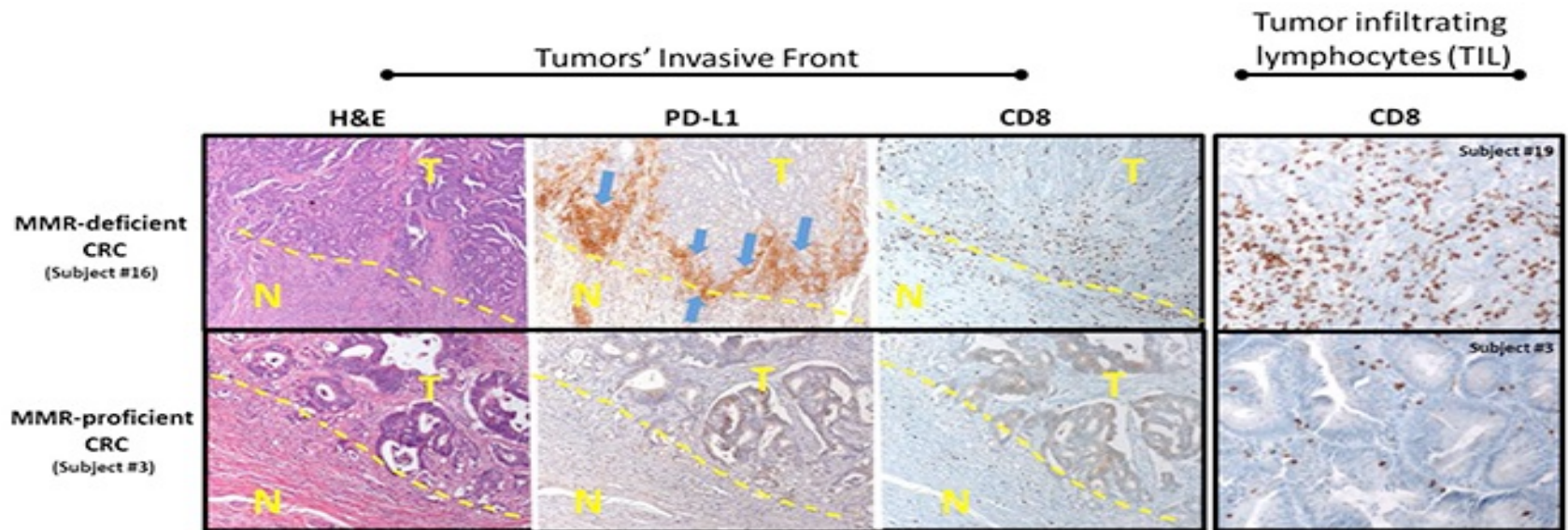
- Builds on hypothesis of neoantigens from somatic mutations
- Phase 2 study
- Three parallel cohorts
 - MMR-proficient CRC
 - MMR-deficient CRC
 - MMR-deficient other



Le DT 2015

Tumor-stromal interface

Pembrolizumab at the tumor-stroma interface



Le DT 2015

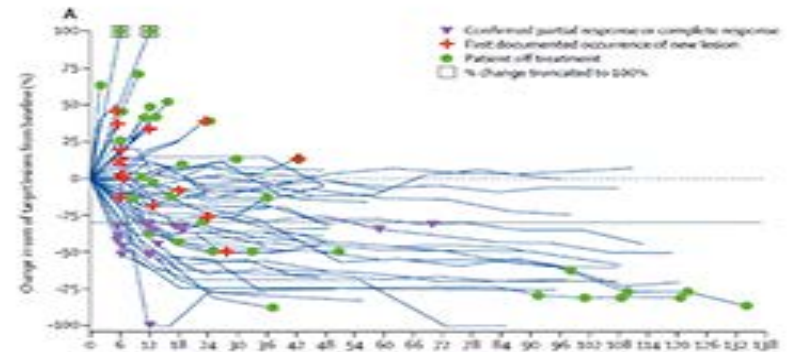


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Nivolumab for highly mutated colorectal cancer

Nivolumab for highly mutated colorectal cancer

- CheckMate 142
- dMMR or microsatellite instability-high (MSI-H)
- 53 patients verified dMMR/MSI-H
- OR 36% (19/53)
- CR 2% (1/53)



**FDA approval for
dMMR/MSI-H tumors in
July 2017**

Checkpoint blockade

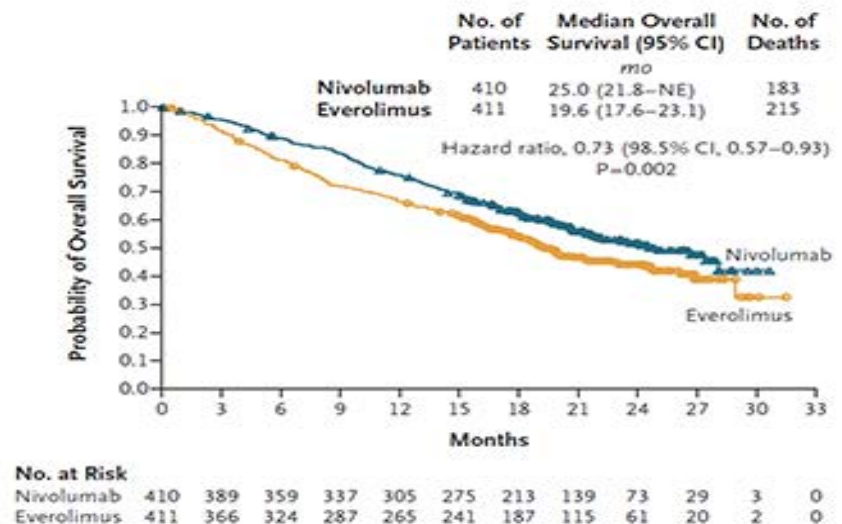
Checkpoint Blockade

- Highly mutated tumors
 - Melanoma
 - Non-small cell lung cancer
 - Bladder cancer
 - Tumors with mismatch repair deficiency
- Use in other tumors?
 - Renal cell
 - Responds to other immunotherapy
 - Hodgkin's lymphoma
 - Reed-Sternberg cells have elevated amounts of PD-L1
 - Head and neck SCC
 - HPV and mutations

Renal cell cancer

Nivolumab for renal cell cancer

- Nivolumab vs everolimus
- Objective Response
 - Nivolumab 103/410 (25%)
 - Everolimus 22/411 (5%)
- Median Survival
 - Nivolumab 25.0 months
 - Everolimus 19.6 months



FDA approval for renal cell carcinoma in November 2015

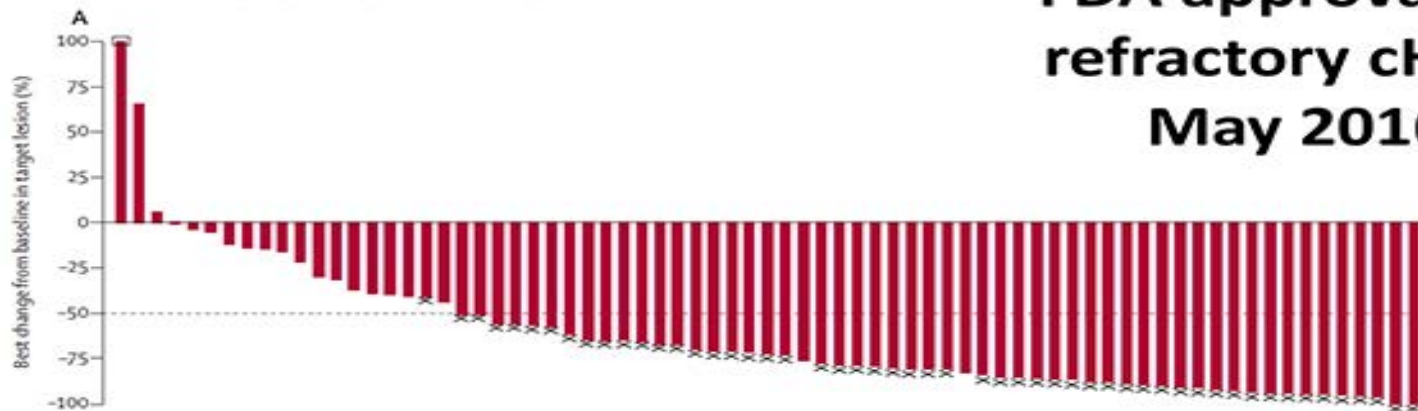
Motzer 2015

Hodgkin's lymphoma

Nivolumab for Hodgkin's Lymphoma

- 80 patients
 - Refractory to stem cell transplant
 - Refractory to brentuximab
- Objective Response
 - 53/80 (66%)
 - 7 complete remission

**FDA approval for
refractory cHL in
May 2016**

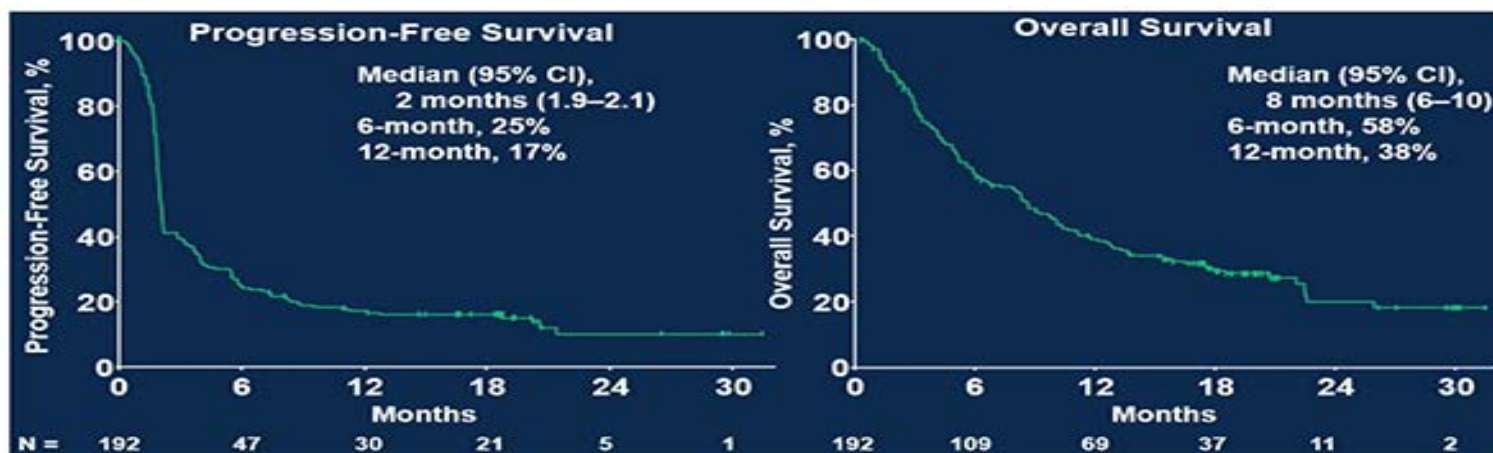


Younes A 2016

THE LANCET **Oncology**

Pembrolizumab

Pembrolizumab in Head and Neck SCC

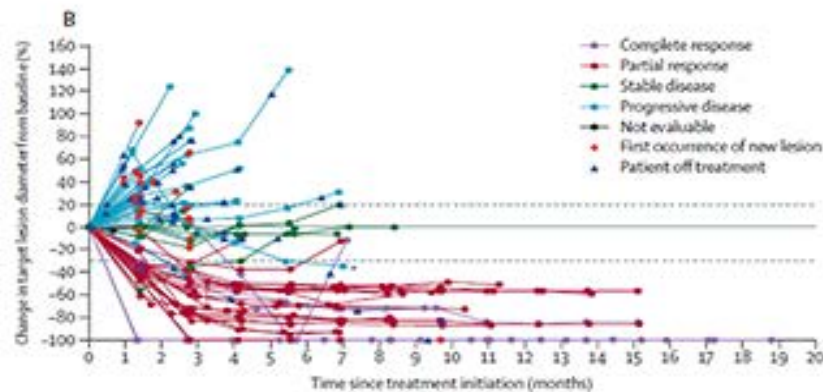


**FDA approval for recurrent or
metastatic head and neck squamous
carcinoma in August 2016**

Avelumab

Avelumab in Merkel cell carcinoma

- 88 patients
 - Confirmed metastatic disease
- Objective Response
 - 28/88 (32%)
 - 8 complete remission



**FDA approval for
Merkel cell
carcinoma in March
2017**

PD-1/PD-L1 pathway

Blocking the PD-1/PD-L1 pathway

	Drug	Melanoma	NSCLC	RCC	Bladder
Anti-PD-1	Nivolumab	32% (n=107)	17% (n=129) 30% (n=20)	29% (n=34) 21% (n=168)	NR
	Pembrolizumab	38% (n=135) 26% (n=157)	26% (n=42) 20% (n=194)	NR	24% (n=29)
Anti-PD-L1	BMS-936559	17% (n=52)	10% (n=49)	12% (n=17)	NR
	MEDI4736	NR	16% (n=58)	NR	NR
	Atezolizumab	30% (n=43)	23% (n=53)	14% (n=56)	26% (n=65)

FDA Approved
(As of 9/2016)

Adapted from Lipson 2015

PD-1/PD-L1 blockade

PD-1/PD-L1 blockade in mBrCa

Trial Characteristics	PD-L1 Status	Drug	Author	Ref.	n	OR	CR
KEYNOTE-12 mTNBC	PD-L1+ (≥1%)	pembrolizumab	Nanda	JCO 2016	27	5 (18.5%)	1
KEYNOTE-28 ER+/Her2-	PD-L1+ (≥1%)	pembrolizumab	Rugo	SABCS 2015	25	3 (12%)	0
KEYNOTE-86 Cohort A mTNBC (refractory)	N/A	pembrolizumab	Adams	ASCO 2017	170	8 (4.7%)	1
KEYNOTE-86 Cohort B mTNBC (1 st line)	PD-L1+ (≥1%)	pembrolizumab	Adams	ASCO 2017	52	12 (23%)	2
JAVELIN Phase Ib Subgroup: mTNBC Sub-subgroup: PD-L1+	N/A (≥10%)	avelumab	Dirix	SABCS 2016*	168 58 9	8 (4.8%) 5 (8.6%) 4 (44%)	1 0 0
mTNBC Subgroup: 1 st line Subgroup: PD-L1+	N/A (≥5%)	atezolizumab	Schmid	AACR 2017	112 19 71	11 (10%) 5 (26%) 9 (13%)	3 2 3

N/A: accepted patients regardless of PD-L1 status

* Initial data presented by Dirix, updated in material requested from EMD/Serrano

Pembrolizumab in Gastric Cancer

- Part of KEYNOTE-012
- Required $\geq 1\%$ PD-L1 staining (65/162, 40%)
- 10 mg/kg q2w
- 39 patients
- OR 22%
- Grade ≥ 3 AE 10%

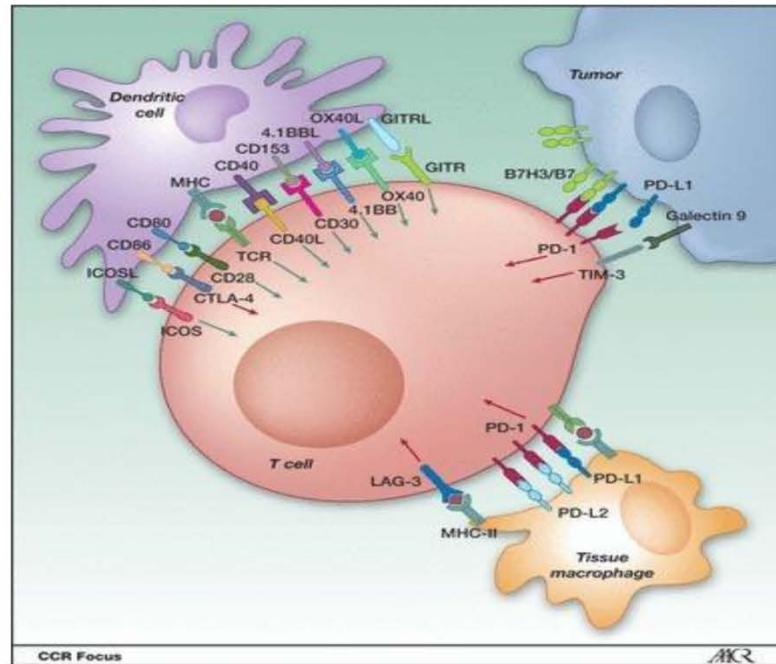
PD-1/PD-L1 blockade

PD-1/PD-L1 blockade at ASCO 2016/7

Disease	Drug	Author	n	OR	CR
Sarcoma	nivolumab	Paoluzzi	14	3 (21%)	0
Uterine leiomyosarcoma	nivolumab	George	12	0	0
Small cell lung cancer	nivo3	Antonia	98	10 (10%)	0
	nivo1+ipi3		61	14 (23%)	2
	nivo3+ipi1		54	10 (19%)	0
Salivary gland cancer	pembrolizumab	Cohen	26	3 (11.5%)	0
Cervical cancer	pembrolizumab	Frenel	24	4 (17%)	0
Endometrial cancer	pembrolizumab	Ott	24	3 (13%)	0
Esophageal cancer	pembrolizumab	Doi	23	7 (30%)	0
Thyroid cancer	pembrolizumab	Mehnert	22	2 (9%)	0
Gastric/GEJ	avelumab	Chung	151	14 (9%)	2
Adrenocortical cancer	avelumab	Le Tourneau	37	2/19 (10%)	0
Ovarian cancer	avelumab	Disis	124	12 (9.7%)	0
Mesothelioma	avelumab	Hassan	53	5 (9.4%)	0
Hepatocellular (liver) cancer	durvalumab	Wainberg	39	4 (10%)	0
Glioblastoma	durvalumab	Reardon	30	4 (13%)	0

Checkpoint modulation

Checkpoint Modulation



Questions?