



VII SIMPOSIO GETTHI

Sesión 4: Vías de desarrollo de la oncología transversal (II)

16 de diciembre de 2021

ALTERACIONES EN KRAS. IMPLICACIONES CLÍNICAS Y NUEVAS ALTERNATIVAS TERAPÉUTICAS

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Servicio de Oncología Médica - EOXI Santiago de Compostela e Barbanza

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IMPORTANCIA DE LA MUTACIÓN RAS

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PREVALENCIA DE LA MUTACIÓN RAS EN TUMORES

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INHIBICIÓN DE LA VÍA RAS G12C

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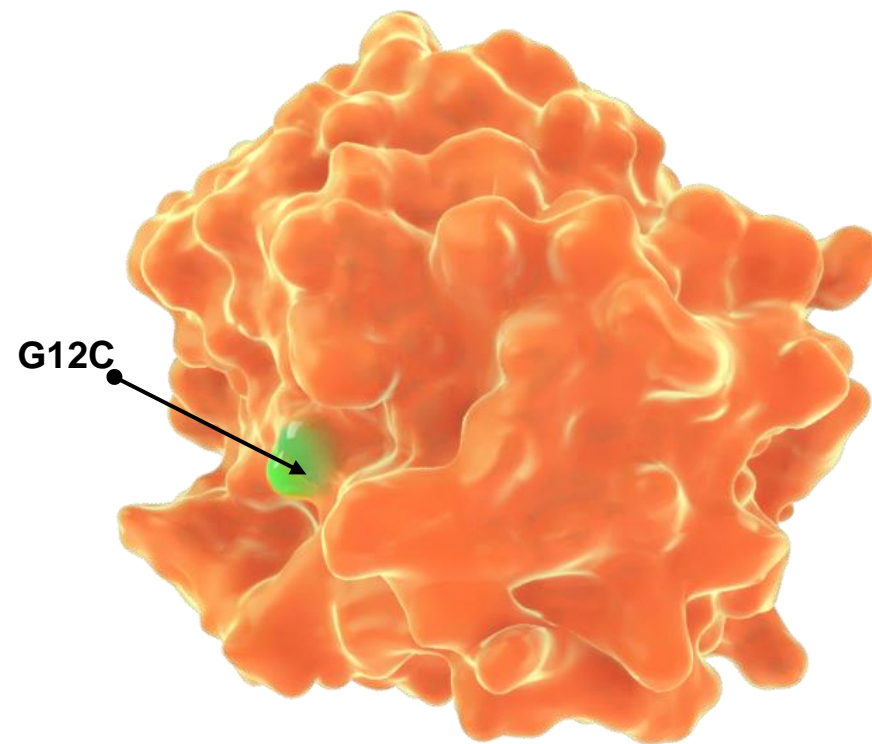
MECANISMOS DE RESISTENCIA A LA INHIBICIÓN RAS G12C

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CONCLUSIONES

KRAS in an Oncogene in human cancers

- Kirsten rat sarcoma viral oncogene homolog (*KRAS*) is one the most frequently mutated oncogenes in human cancers¹
- Despite the discovery of *KRAS* almost 4 decades ago, there is currently no approved therapy targeting *KRAS*¹
- *KRAS* G12C mutation (glycine to cysteine substitution at position 12) promotes tumorigenesis and is found in approximately 13% of NSCLC, **3–5% of colorectal cancer, and 1%–3% of other solid tumors**^{2–7}



***KRAS* G12C**

GDP, guanosine diphosphate; H95, histidine amino acid at position 95; *KRAS*, Kirsten rat sarcoma viral oncogene homolog; NSCLC, non-small cell lung cancer; Q99, glutamine amino acid at position 99; Y96, tyrosine amino acid at position 96.

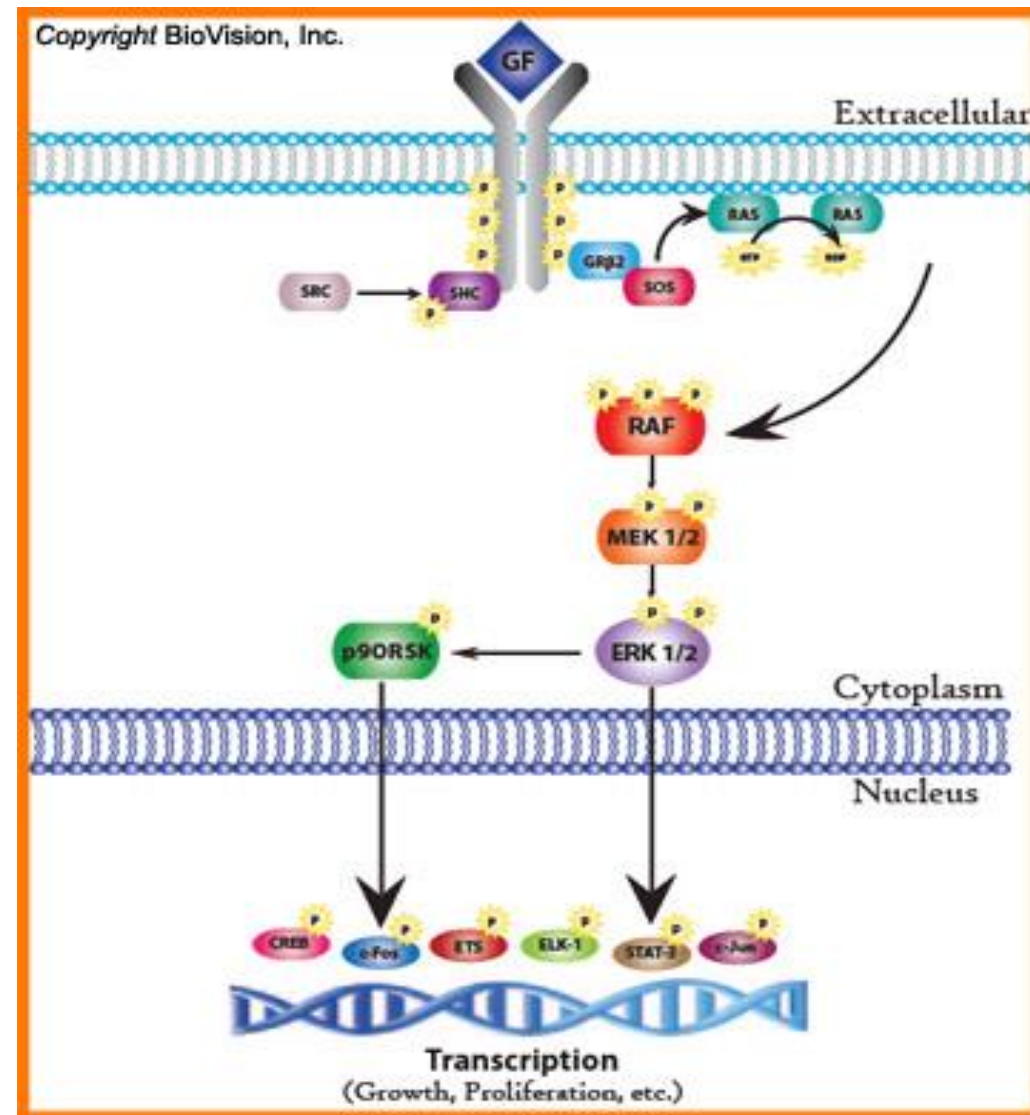
1. Cox AD, et al. *Nat Rev Drug Discov.* 2014;13:828-851. 2. Biernacka A, et al. *Cancer Genet.* 2016;209:195-198. 3. Neumann J, et al. *Pathol Res Pract.* 2009;205:858-862. 4. Jones RP, et al. *Br J Cancer.* 2017;116:923-929. 5. Wiesweg M, et al. *Oncogene.* 2019;38:2953-2966. 6. Zhou L, et al. *Med Oncol.* 2016;33:32. 7. Canon J, et al. *Nature.* 2019;575:217-223.

KRAS mutations impairing GTPase activity are well known to play pivotal role in oncogenic transformation

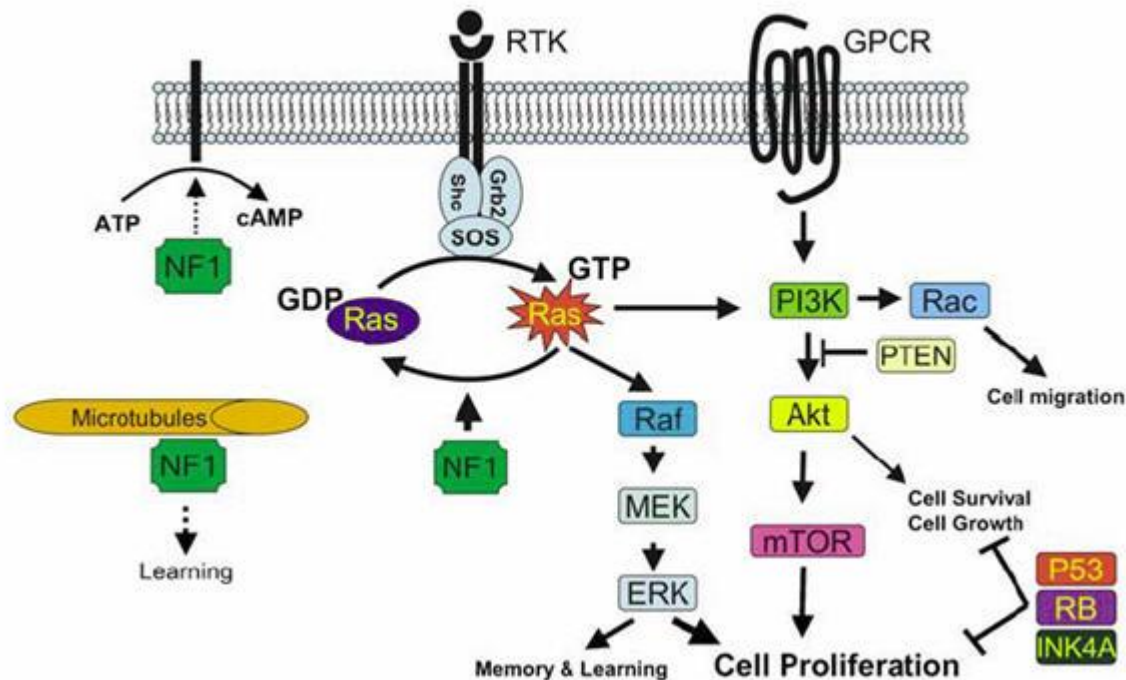
↳ *KRAS*-mutated tumors represents a genetically heterogenous subgroup

ONCOGENE RAS:

- Cytoskeletal integrity
- Cell proliferaci3n
- Cell differentiation
- Cell adhesion
- Cell migration
- Apoptosis



Role of RAS mutated in cancer



Ras activates several pathways, of which the [mitogen-activated protein \(MAP\) kinase cascade](#) has been well-studied.

This cascade transmits signals downstream and results in the [transcription](#) of genes involved in cell growth and division.

Another Ras-activated signaling pathway is the [PI3K/AKT/mTOR pathway](#), which stimulates protein synthesis and cellular growth, and inhibits apoptosis.

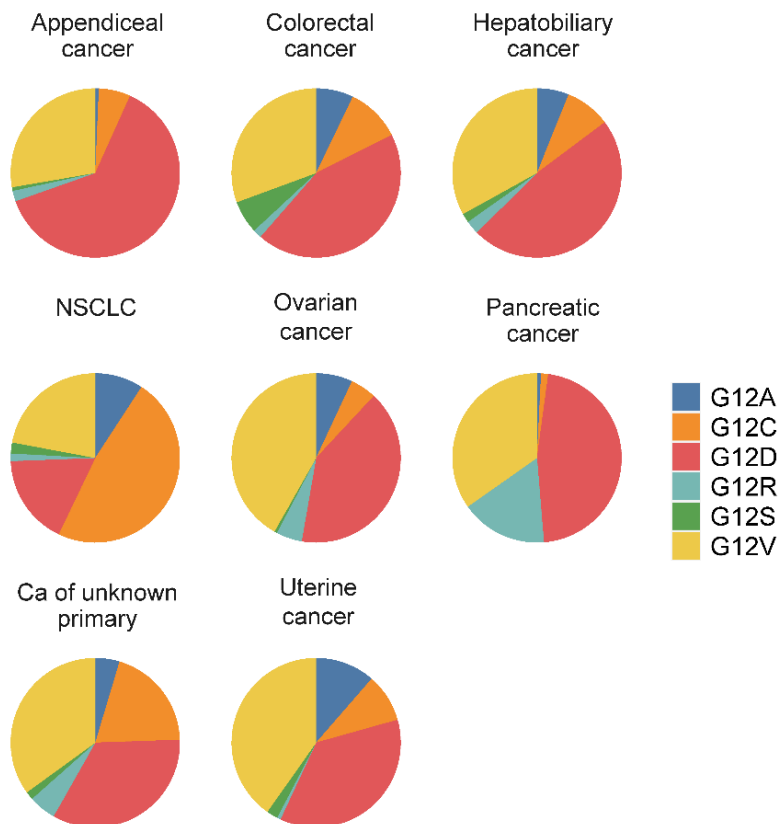
PREVALENCE OF RAS MUTATION RAS IN CANCER



- *RAS* codon 12, 13 and 61 mutation prevalence is cancer type-dependent.

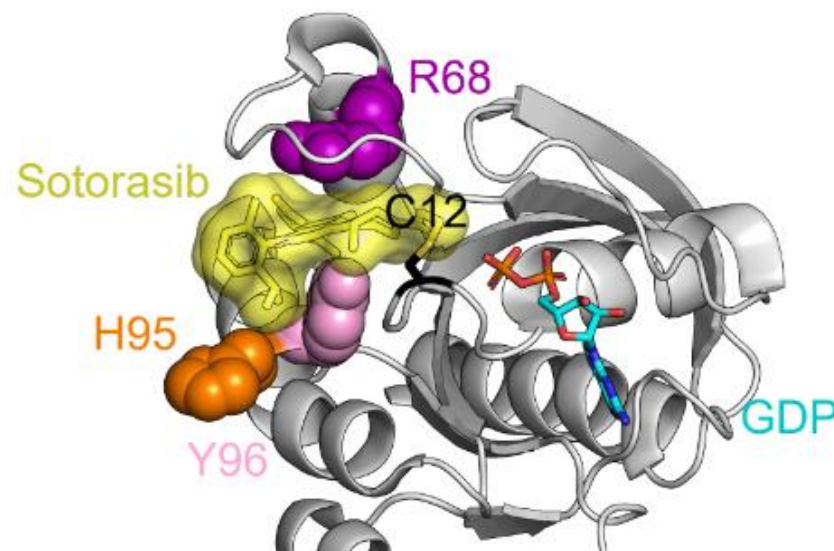
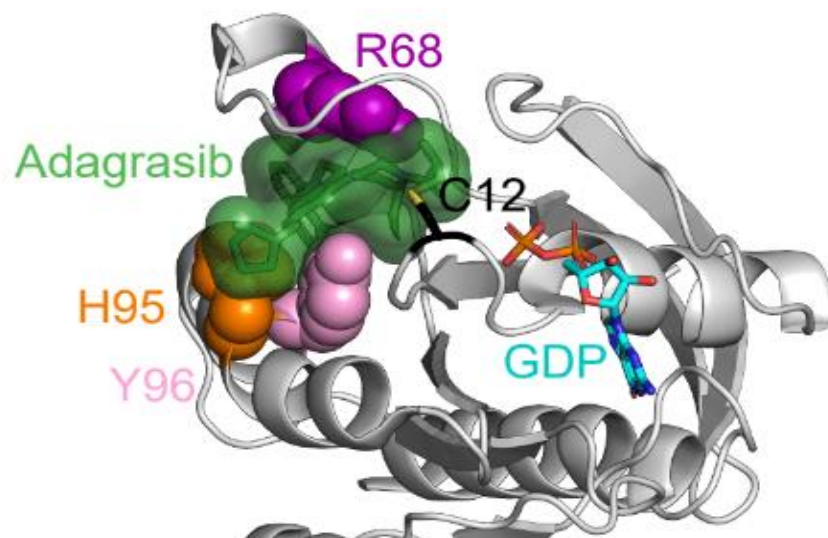
- 77.7% in pancreatic cancer
- 44.8% in colorectal cancer
- 31.2% in NSCLC
- 1.1% in breast cancer
- 0.5% in mesothelioma

SEVERAL RAS MUTATIONS



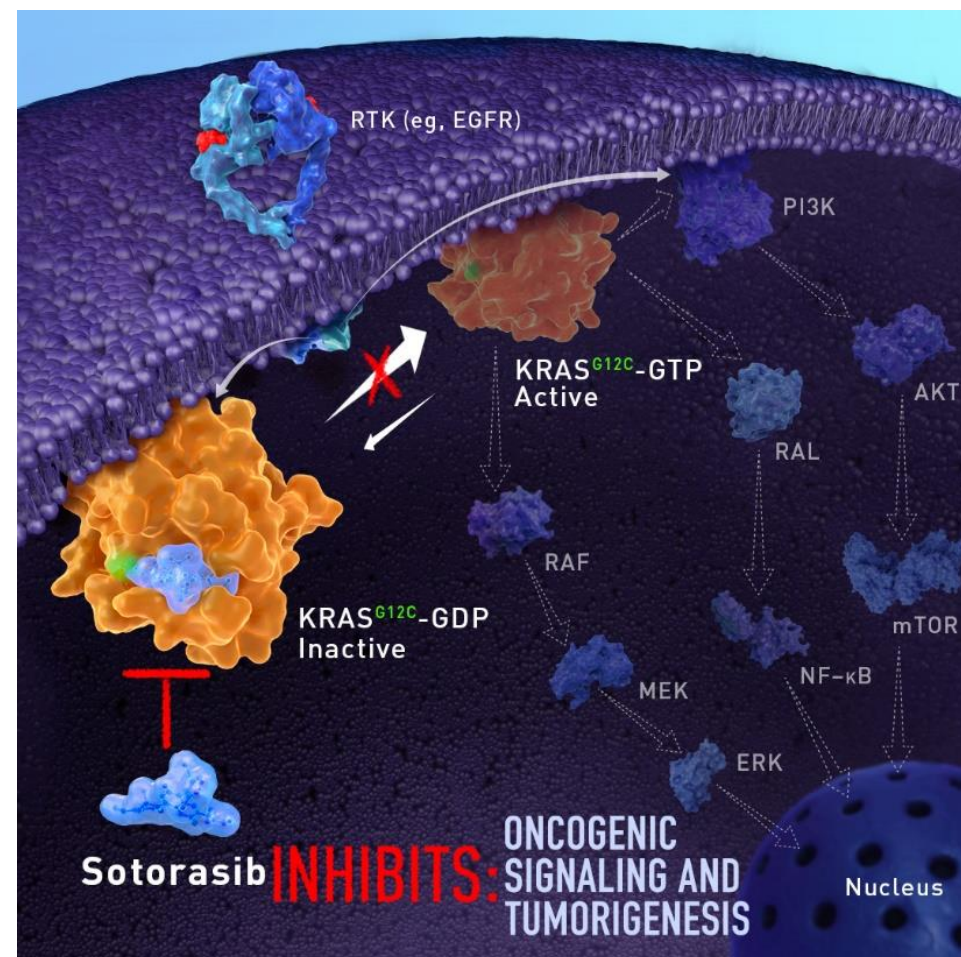
- The type of substitution at codon 12 is tissue-specific.
- 48% G12C in NSCLC vs. 10% in CRC and 1% in PAC.
- 47% G12D in PAC and 44% in CRC vs. 17% in NSCLC.
- 17% G12R in PAC vs. 1% in NSCLC and 2% in CRC.
- G12V comprises a third of codon 12 mutations.
- G12A and G12S less frequent among all tumor types.

G12C RAS MUTATION INHIBITION



SOTORASIB

- Sotorasib is a first-in-class, oral targeted therapy that selectively inhibits the KRAS^{G12C} protein¹
- Sotorasib locks the KRAS^{G12C} mutant protein in an inactive state, preventing oncogenic signaling without affecting wild-type KRAS signaling¹⁻³



1. Canon J, et al. *Nature*. 2019; 575:217-223.

2. Hong DS, et al. *N Engl J Med*. 2020;383:1207-1217

Phase 1 Study Design

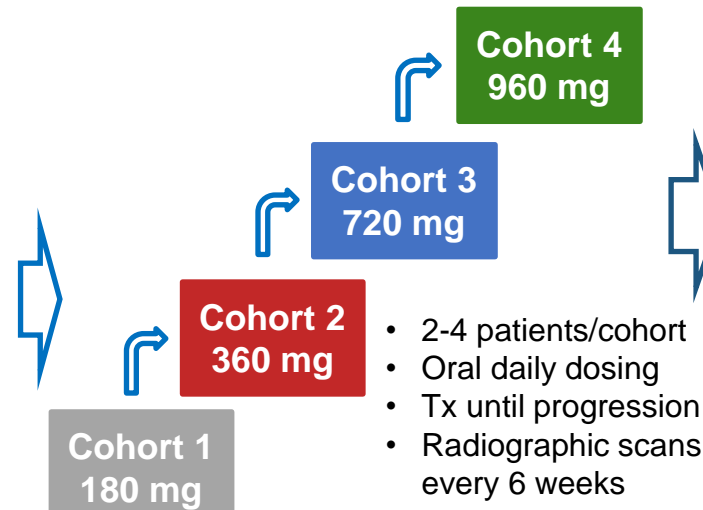
Phase 1, Multicenter, Open-label Study – Dose Escalation

Dose Expansion

Key Eligibility

- Locally advanced or metastatic malignancy
- Received prior standard therapies
- *KRAS G12C* mutation as assessed by molecular testing of tumor biopsies
- No active brain metastases

Screening / Enrollment



Safety Follow-up &
Long-term Follow-up*

Expansion
dose
determined

Screening / Enrollment

Patients with
KRAS G12C
mutant advanced
tumors
N~20
(maximum 60)

Safety Follow-up &
Long-term Follow-up*

Primary endpoint: Safety, including DLTs

Secondary endpoints include: PK; ORR; DOR; DCR; PFS; duration of SD

*30 (+7) days after end of treatment for safety follow-up; every 12 weeks for long-term follow-up.

DCR, disease control rate; DOR, duration of response; *KRAS*, Kirsten rat sarcoma viral oncogene homolog; ORR, objective response rate; PFS, progression-free survival; PK, pharmacokinetic; SD, stable disease; Tx, treatment.

Hong DS. Oral presentation at European Society of Medical Oncology 2020 Virtual Congress, September 19-21, 2020.

CODEBREAK 100- Phase II

Screening / Enrollment

Key Eligibility:

- Locally advanced or metastatic NSCLC
- *KRAS* G12C mutation as assessed by central testing of tumor biopsies
- Progressed on prior standard therapies^a
- No active brain metastases

Sotorasib was orally administered at 960 mg once daily until disease progression^b

Radiographic scan every 6 weeks up to week 48 and once every 12 weeks thereafter

Primary endpoint: ORR (RECIST 1.1) by blinded independent central review

Key secondary endpoints: DoR; disease control rate; TTR; PFS; OS; safety

Exploratory endpoints: Evaluation of biomarkers (PD-L1, co-occurring mutations)

Safety and Long-term Follow-up^c

a: no more than 3 prior lines of therapies were allowed; **b:** treatment beyond disease progression was allowed if certain criteria were met; **c:** safety follow-up occurs 30 (+7) days after the last dose of sotorasib; long-term follow-up occurs every 12 (±2) weeks for up to 3 years.

DoR, duration of response; **KRAS**, Kirsten rat sarcoma viral oncogene homolog; **NSCLC**, non-small cell lung cancer; **ORR**, objective response rate; **OS**, overall survival; **PD-L1**, programmed death-ligand 1; **PFS**, progression-free survival; **RECIST**, Response Evaluation Criteria in Solid Tumors; **TTR**, time to response.

Li BT, et al. Presentation at 2020 World Congress on Lung Cancer Singapore Worldwide Virtual Event, January 28-31, 2021. Abstract PS01.07.

Tumor Response with Sotorasib

Response assessed by central review	Sotorasib 960mg, N = 124 ^a
Confirmed objective response rate – % (95% CI)	37.1 (28.6, 46.2)
Best overall response – n (%)	
Complete response	3 (2.4)
Partial response	43 (34.7)
Stable disease	54 (43.5)
Progressive disease	20 (16.1)
“Not evaluable” or “Missing scan” ^b	4 (3.2)
Disease control rate – % (95% CI)	80.6 (72.6, 87.2)

Over 80% of patients achieved disease control, including 3 CRs and 43 PRs

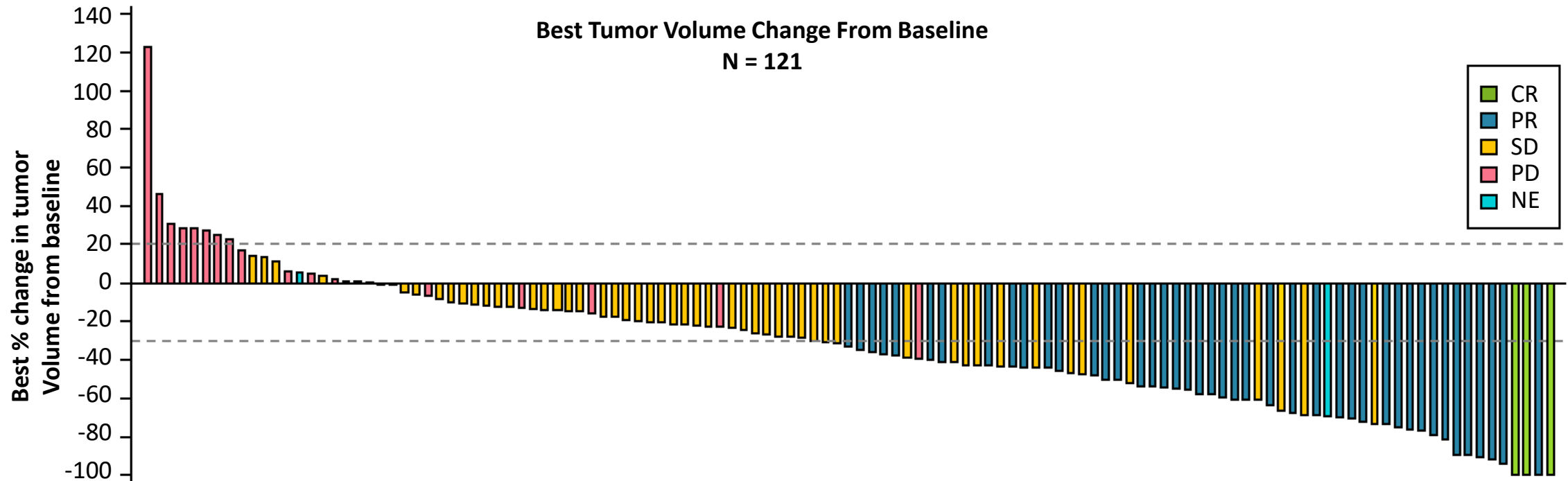
a: according to central review, 2 patients did not have measurable lesions at baseline per RECIST 1.1 and were excluded from response assessment;

b: 2 patients stopped treatment without post-baseline scans and were deemed as “missing scan”; 2 patients had 1 post-baseline scan and were assessed as “not evaluable” by central review.

CI, confidence interval; **CR**, complete response; **PR**, partial response.

Li BT, et al. Presentation at 2020 World Congress on Lung Cancer Singapore Worldwide Virtual Event, January 28-31, 2021. Abstract PS01.07.

Depth of Tumor Response



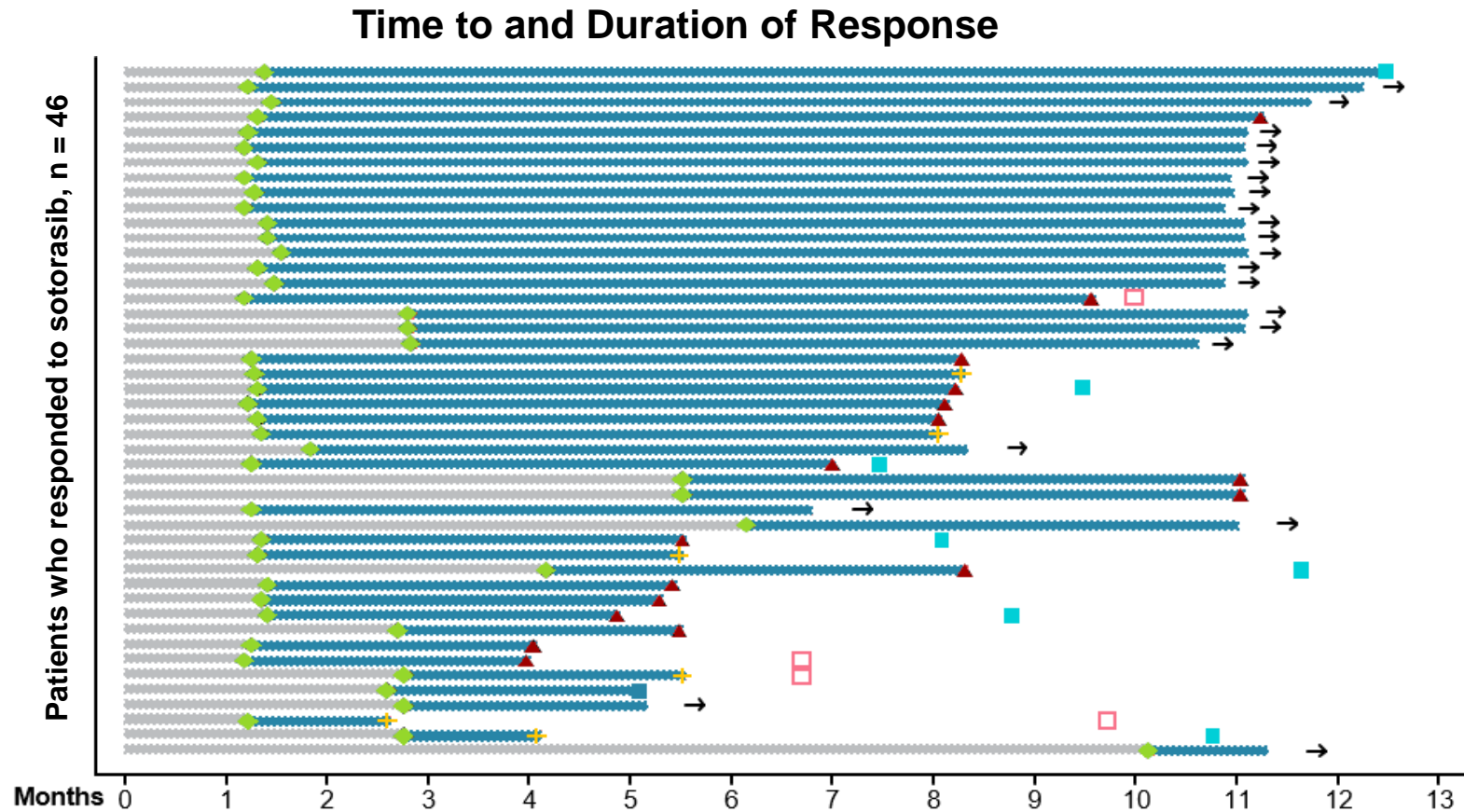
Tumor shrinkage of any magnitude was observed in 81% of patients (101/124)
Median percentage of best tumor shrinkage among all responders was 60%

Graph excluded 3 patients without post-baseline measurement in target lesions.

CR, complete response; **NE**, not evaluable; **PD**, progressive disease; **PR**, partial response; **SD**, stable disease.

Li BT, et al. Presentation at 2020 World Congress on Lung Cancer Singapore Worldwide Virtual Event, January 28-31, 2021. Abstract PS01.07.

Durability of Tumor Response



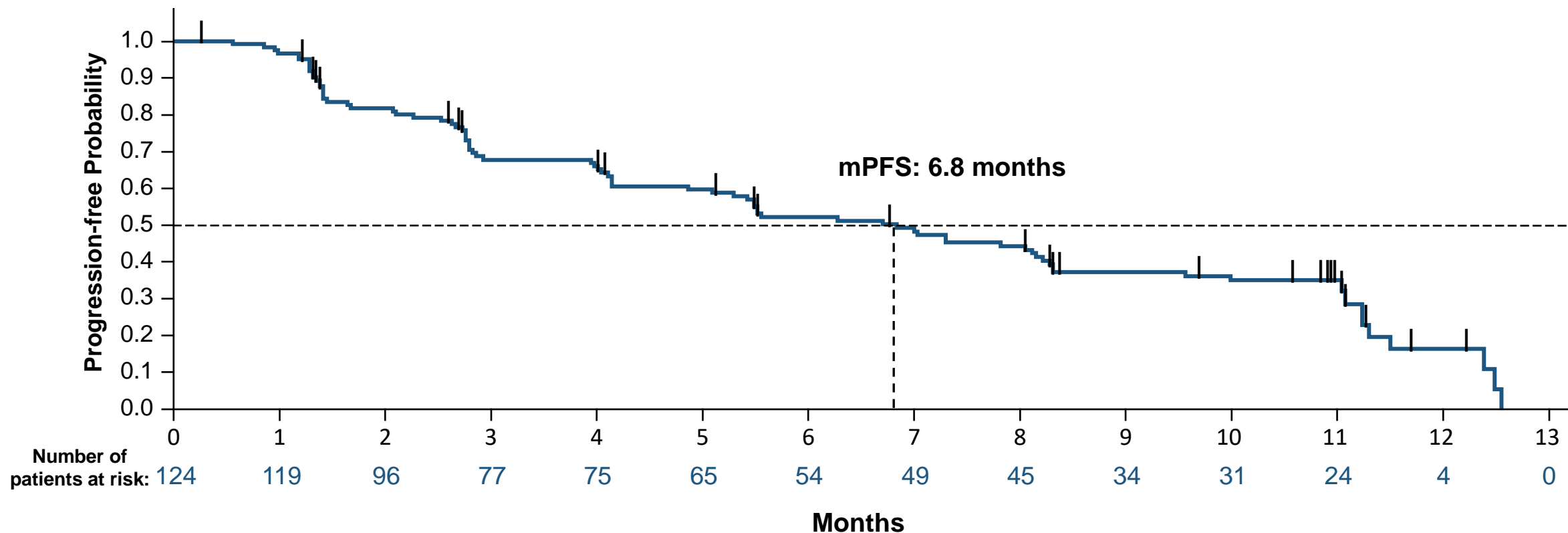
- Median duration of response:
– **10.0 months** (95% CI: 6.9, 11.1)
- Median time to objective response:
– **1.4 months**
- **43%** (20/46) of responders remained on treatment without progression as of the data cutoff

Responses to sotorasib were durable; 72% were seen at the first assessment

CI, confidence interval; OS, overall survival; PFS, progression-free survival.

Li BT, et al. Presentation at 2020 World Congress on Lung Cancer Singapore Worldwide Virtual Event, January 28-31, 2021. Abstract PS01.07.

Progression-Free Survival



Median progression-free survival was 6.8 months (95% CI: 5.1, 8.2)

CI, confidence interval; mPFS, median progression-free survival.

Li BT, et al. Presentation at 2020 World Congress on Lung Cancer Singapore Worldwide Virtual Event, January 28-31, 2021. Abstract PS01.07.

Treatment-Related Adverse Events

Treatment-related adverse events (TRAEs) occurring in > 5%, n (%)	Any Grade N = 126	Grade 3 N = 126
Any event	88 (69.8)	25 (19.8)
Diarrhea	39 (31.0)	5 (4.0)
Nausea	24 (19.0)	0
ALT increase	19 (15.1)	8 (6.3)
AST increase	19 (15.1)	7 (5.6)
Fatigue	14 (11.1)	0
Vomiting	10 (7.9)	0
Blood alkaline phosphatase increase	9 (7.1)	1 (0.8)
Maculopapular rash	7 (5.6)	0

- Most TRAEs were grade 1 or 2
- No fatal TRAEs occurred
- TRAEs led to treatment discontinuation in 7.1% of patients
- TRAEs led to dose modification in 22.2% of patients

1 patient (0.8%) reported grade 4 TRAEs (pneumonitis and dyspnea)

Treatment-related adverse events were generally mild and manageable

ALT, alanine aminotransferase; **AST**, aspartate aminotransferase.

Li BT, et al. Presentation at 2020 World Congress on Lung Cancer Singapore Worldwide Virtual Event, January 28-31, 2021. Abstract PS01.07.

CODEBREAK 100- SOTORASIB

- Sotorasib, the first-in-class KRAS^{G12C} inhibitor administered as once daily oral therapy, demonstrated early, deep, and durable responses in the advanced NSCLC cohort from the phase 2 CodeBreak 100 trial
 - ORR was 37.1%, with median DoR of 10.0 months and median PFS of 6.8 months, validating the phase 1 results
- Sotorasib was well tolerated with no deaths attributed to treatment and low incidence of grade 3 or 4 treatment-related adverse events, treatment discontinuation, and dose modification
- Tumor response to sotorasib was observed across a range of biomarker subgroups, including patients with negative or low PD-L1 expression level and those with mutant *STK11*
- Breakthrough therapy designation was granted by FDA; regulatory filings based on current data are underway
- Confirmatory phase 3 CodeBreak 200 trial is currently enrolling (clinicaltrials.gov identifier: NCT04303780)

DoR, duration of response; FDA, Food and Drug Administration **KRAS**, Kirsten rat sarcoma viral oncogene homolog; **NSCLC**, non-small cell lung cancer; **ORR**, objective response rate; **PD-L1**, programmed death ligand 1; **PFS**, progression-free survival; **STK11**, serine/threonine kinase 11; **TMB**, tumor mutational burden.

Li BT, et al. Presentation at 2020 World Congress on Lung Cancer Singapore Worldwide Virtual Event, January 28-31, 2021. Abstract PS01.07.

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Clinical Trial	ClinicalTrials.gov NCT ID	Treatments	Advanced KRAS G12C-Mutated Cancers			Phase
			NSCLC	CRC	Other Solid Tumors	
CodeBreak 200	NCT04303780	Monotherapy vs. docetaxel	<div><div></div></div>			3
		Monotherapy	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	2
CodeBreak 100	NCT03600883	Monotherapy (240 mg)	<div><div></div></div>			2
		Monotherapy (treatment naïve)	<div><div></div></div>		<div><div></div></div>	1
		+ PD-1/PD-L1 inhibitor	<div><div></div></div>		<div><div></div></div>	1
		+ Oral EGFR inhibitor	<div><div></div></div>			1b
CodeBreak 101	NCT04185883	+ PD-L1 inhibitor	<div><div></div></div>			1b
		+ Chemotherapy	<div><div></div></div>			1b
		+ EGFR Ab +/- Chemotherapy	<div><div></div></div>	<div><div></div></div>		1b
		+ VEGF Ab + Chemotherapy	<div><div></div></div>	<div><div></div></div>		1b
		+ PD-1 inhibitor	<div><div></div></div>			1b
		+ MEK inhibitor +/- EGFR Ab	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	1b
		+ SHP2 inhibitor	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	1b
		+ mTOR inhibitor	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	1b
		+ CDK inhibitor	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	1b
CodeBreak 105	NCT04380753	Monotherapy*	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	1

ADAGRASIB

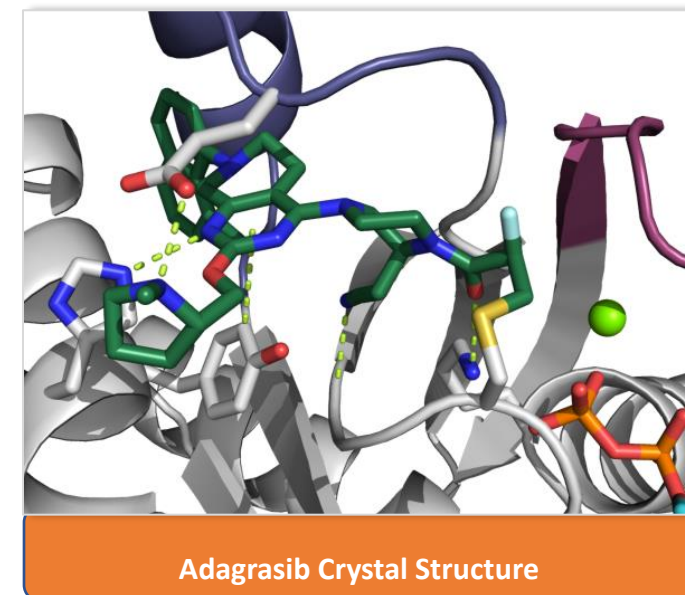
Adagrasib is a covalent inhibitor of KRAS^{G12C} that irreversibly and selectively binds KRAS^{G12C} in its inactive, GDP-bound state

Adagrasib was optimized for desired properties of a KRAS^{G12C} inhibitor:

Potent covalent inhibitor of KRAS^{G12C} (cellular IC₅₀: ~5 nM)

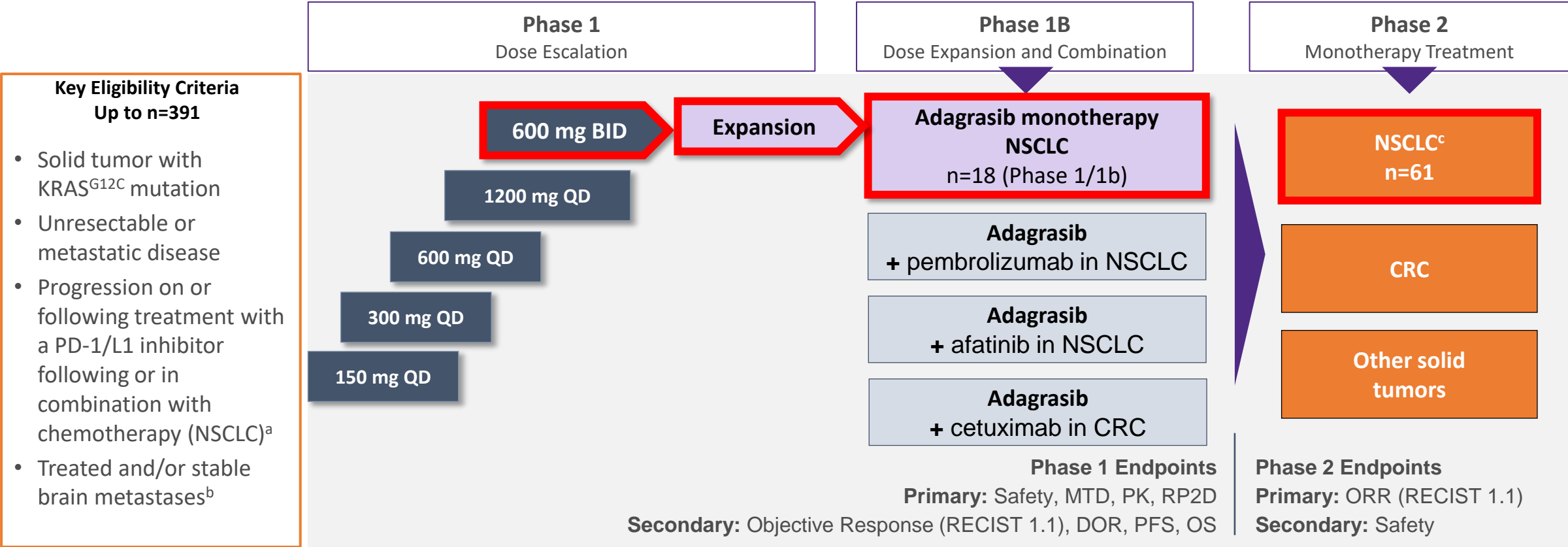
High selectivity (>1000X) for the mutant KRAS^{G12C} protein vs wild-type KRAS

Favorable PK properties, including oral bioavailability, long half-life (~24 h), and extensive tissue distribution



Hypothesis: Maintaining continuous exposure of adagrasib above a target threshold enables inhibition of KRAS-dependent signaling for the complete dose interval and maximizes depth and duration of antitumor activity

KRYSTAL-1 (849-001) Study Design



^aApplies to the majority of NSCLC cohorts. ^bMost cohorts allow patients with brain metastases if adequately treated and stable; additional phase 1/1b cohort allows limited brain metastases. ^cPrimary NSCLC cohort eligibility based on a tissue test; KRAS^{G12C} testing for entry was performed locally or centrally using a sponsor pre-approved test. ClinicalTrials.gov. NCT03785249.

	Phase 1/1b 600 mg BID (n=18)	Phase 1/1b and 2 600 mg BID (n=79)
Median age, y (range)	65 (40-76)	65 (25-85)
Female, n (%)	11 (61%)	45 (57%)
Race, n (%)		
White	15 (83%)	67 (85%)
Black	3 (17%)	5 (6%)
Asian	0 (0%)	5 (6%)
Other	0 (0%)	2 (3%)
ECOG PS, n (%)		
0	8 (44%)	17 (22%)
1	10 (56%)	62 (78%)
Current/former smokers	16 (89%)	75 (95%)
Nonsquamous histology, n (%)	18 (100%)	76 (96%)
Prior lines of anticancer therapy^a, median (range)	3 (1-9)	2 (1-9)
Prior anti-PD-1/L1 inhibitor, n (%)	16 (89%)	73 (92%)

^aPhase 2 patients with NSCLC received prior treatment with platinum regimens.
Data as of 30 August 2020. Pooled includes NSCLC Phase 1/1b and Phase 2 600 mg BID.

Adagrasib in Patients With NSCLC: ORR in Pooled Dataset

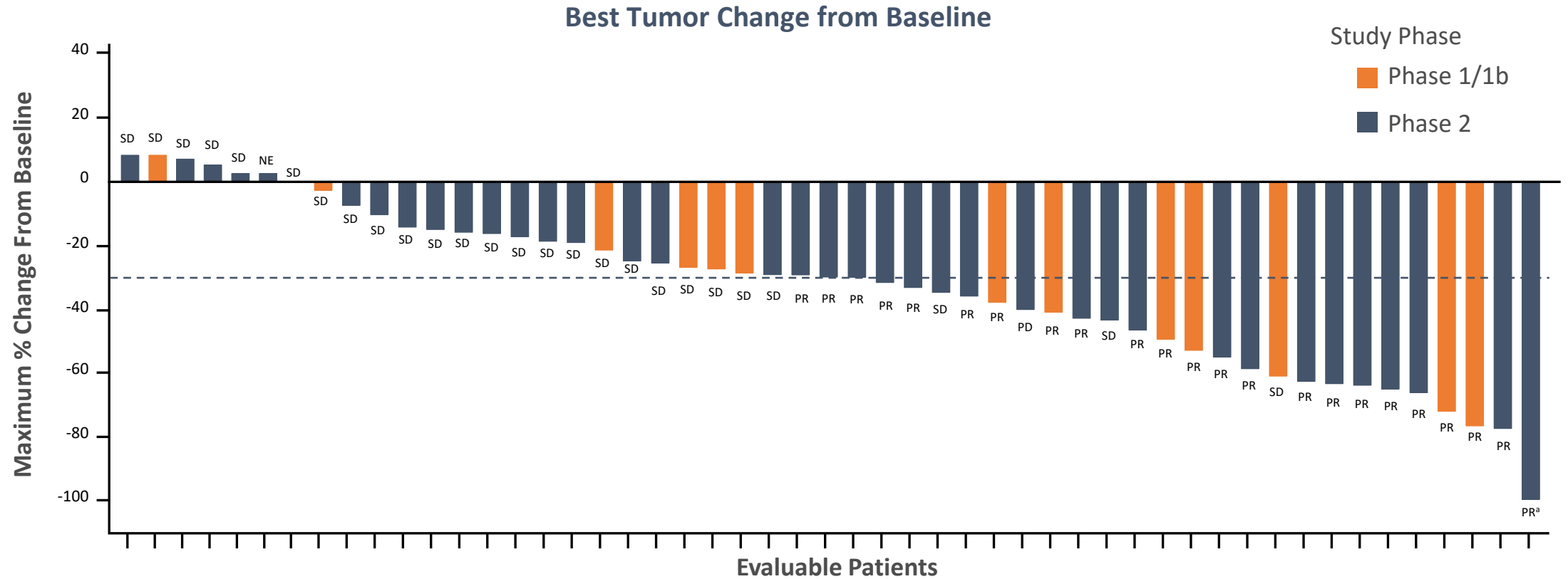
Efficacy Outcome ^a , n (%)	Phase 1/1b, NSCLC 600 mg BID (n=14)	Phase 1/1b and 2, NSCLC 600 mg BID (n=51)
Objective Response Rate	6 (43%)	23 (45%) ^b
Best Overall Response		
Complete Response (CR)	0 (0%)	0 (0%)
Partial Response (PR)	6 (43%)	23 (45%)
Stable Disease (SD)	8 (57%)	26 (51%)
Progressive Disease (PD)	0 (0%)	1 (2%)
Not Evaluable (NE)	0 (0%)	1 (2%) ^c
Disease control	14 (100%)	49 (96%)

^aBased on investigator assessment of the clinically evaluable patients (measurable disease with ≥ 1 on-study scan); 14/18 patients (Phase 1/1b) and 51/79 patients (Phase 1/1b and 2 pooled) met these criteria. ^bAt the time of the 30 August 2020 data cut off, 5 patients had unconfirmed PRs. All 5 were confirmed by scans that were performed after the 30 August 2020 data cut off.

^cOne patient had tumor reimaging too early for response assessment.

Data as of 30 August 2020. Pooled includes NSCLC Phase 1/1b and Phase 2 600 mg BID.

Adagrasib 600 mg BID in Patients With NSCLC: Best Tumor Change From Baseline

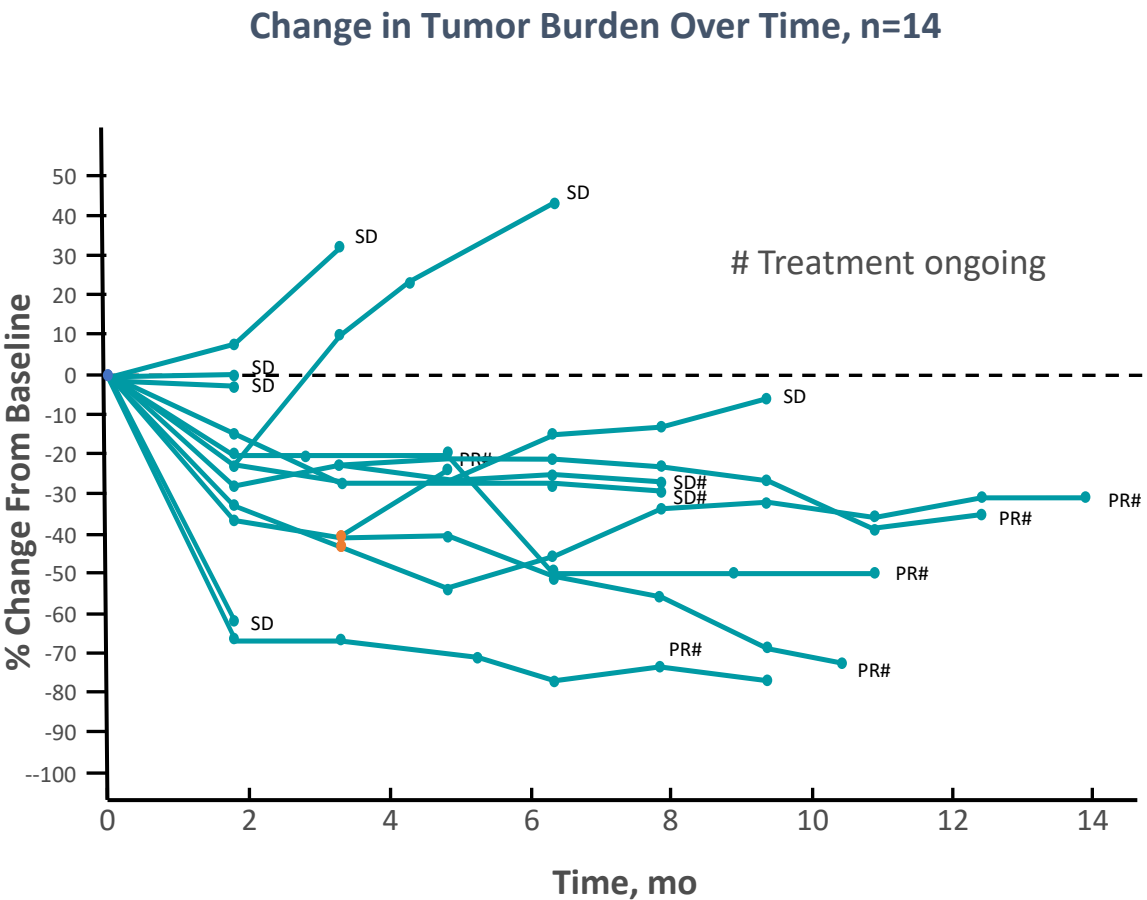
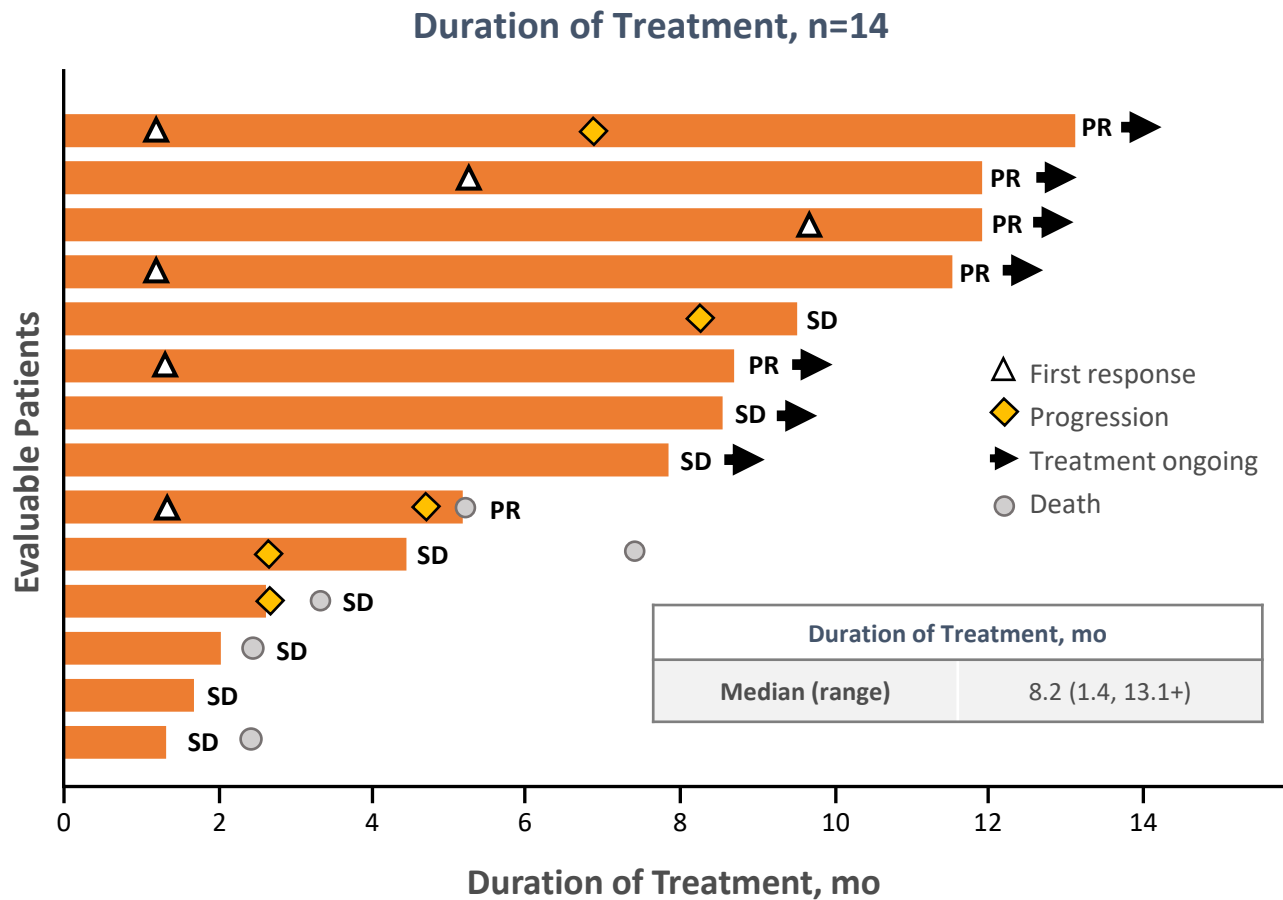


- Clinical benefit (DCR) observed in 96.1% (49/51) of patients

^aTwo timepoint assessments of CR were separated by recurrent disease associated with treatment interruption due to hypoxia; this patient remains on treatment and in two consecutive scans (1 after August 30 data cutoff) demonstrated 100% tumor regression in target and non-target lesions after resuming treatment.

Data as of 30 August 2020. Pooled includes NSCLC Phase 1/1b and Phase 2 600 mg BID.

Adagrasib 600 mg BID in Patients With NSCLC: Treatment Duration and Change in Tumor Burden



- Median follow-up, 9.6 mo
- 5 of the 6 responders remain on treatment; treatment ongoing >11 mo for the majority of patients with responses (4/6)
- Median time to response, 1.5 mo

The Prognostic Impact of *KRAS* G12C Mutation in Patients with Metastatic Colorectal Cancer: A Multicenter Retrospective Observational Study

We demonstrate that, compared with non- G12C mutations, *KRAS* G12C mutation is significantly correlated with shorter first-line PFS and OS.

These findings indicate the relevance of a stratified treatment targeting *KRAS* G12C mutation in mCRC.

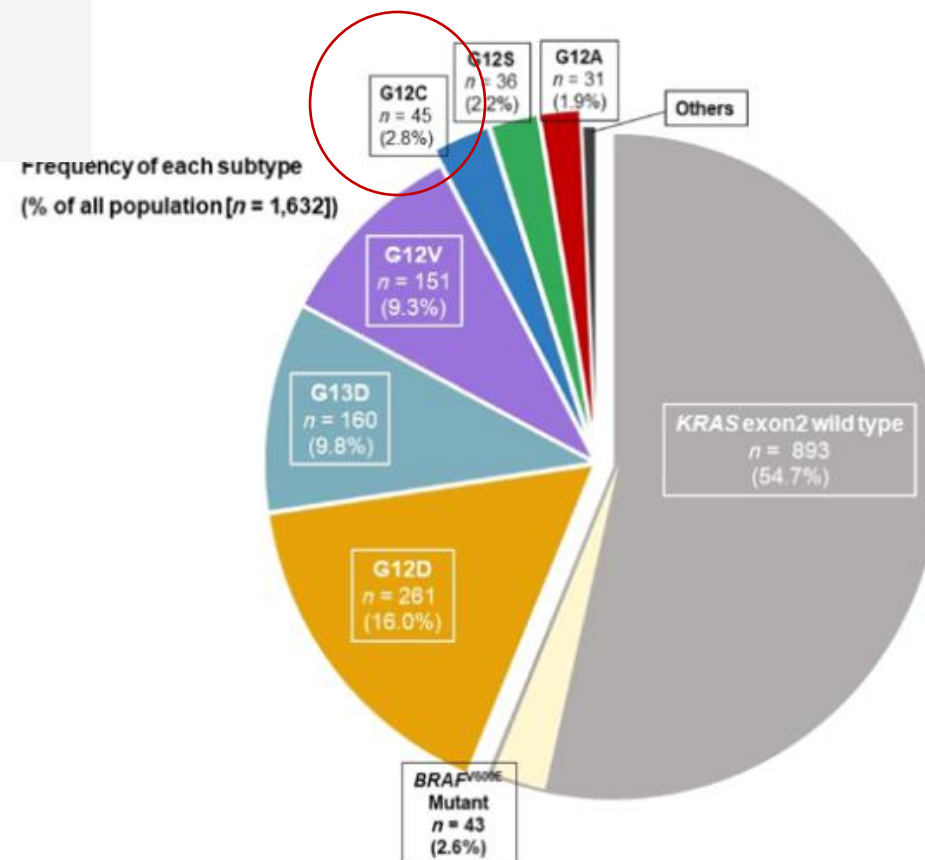


Figure 2. Frequency of each subtype (% of all population). *KRAS* exon 2 wild-type was 56.3%, and the most prevalent mutations in *KRAS* exon 2 were G12D (16.3%), followed by G13D (10.1%), G12V (9.5%), G12C (2.8%), G12S (2.3%), and G12A (1.9%). Abbreviations: *KRAS*, Kirsten rat sarcoma.

The NEW ENGLAND JOURNAL of MEDICINE

KRAS^{G12C} Inhibition with Sotorasib in Advanced Solid Tumors

Table 3. Efficacy of Sotorasib in All Tumor Types.

	NSCLC (N=59)	Colorectal Cancer (N=42)	Other (N=28)
Best overall response — no. (%)			
Confirmed complete response	0	0	0
Confirmed partial response	19 (32.2)	3 (7.1)	4 (14.3)
Stable disease	33 (55.9)	28 (66.7)	17 (60.7)
Progressive disease	5 (8.5)	10 (23.8)	4 (14.3)
Could not be evaluated	1 (1.7)	0	1 (3.6)
No assessment*	1 (1.7)	1 (2.4)	2 (7.1)
Objective response — % (95% CI)†	32.2 (20.62–45.64)	7.1 (1.50–19.48)	14.3 (4.03–32.67)
Disease control — % (95% CI)‡	88.1 (77.07–95.09)	73.8 (57.96–86.14)	75.0 (55.13–89.31)

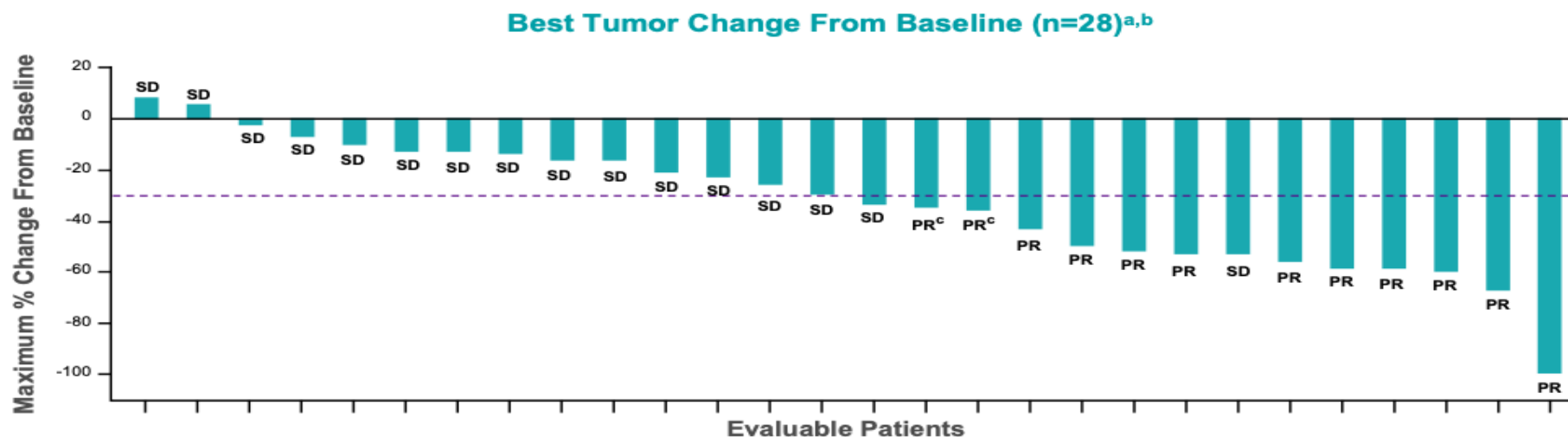
* One patient with NSCLC withdrew consent before tumor assessment. One patient with colorectal cancer and 2 patients with other tumor types had clinical progression.

† Objective response was defined as a complete or partial response.

‡ Disease control was defined as a complete response, a partial response, or stable disease.

ADAGRASIB COLORECTAL CANCER - ESMO 2021

LBA6 - KRYSTAL-1: Adagrasib (MRTX849) as Monotherapy or in Combination With Cetuximab in Patients (Pts) With Colorectal Cancer (CRC) Harboring a KRASG12C Mutation

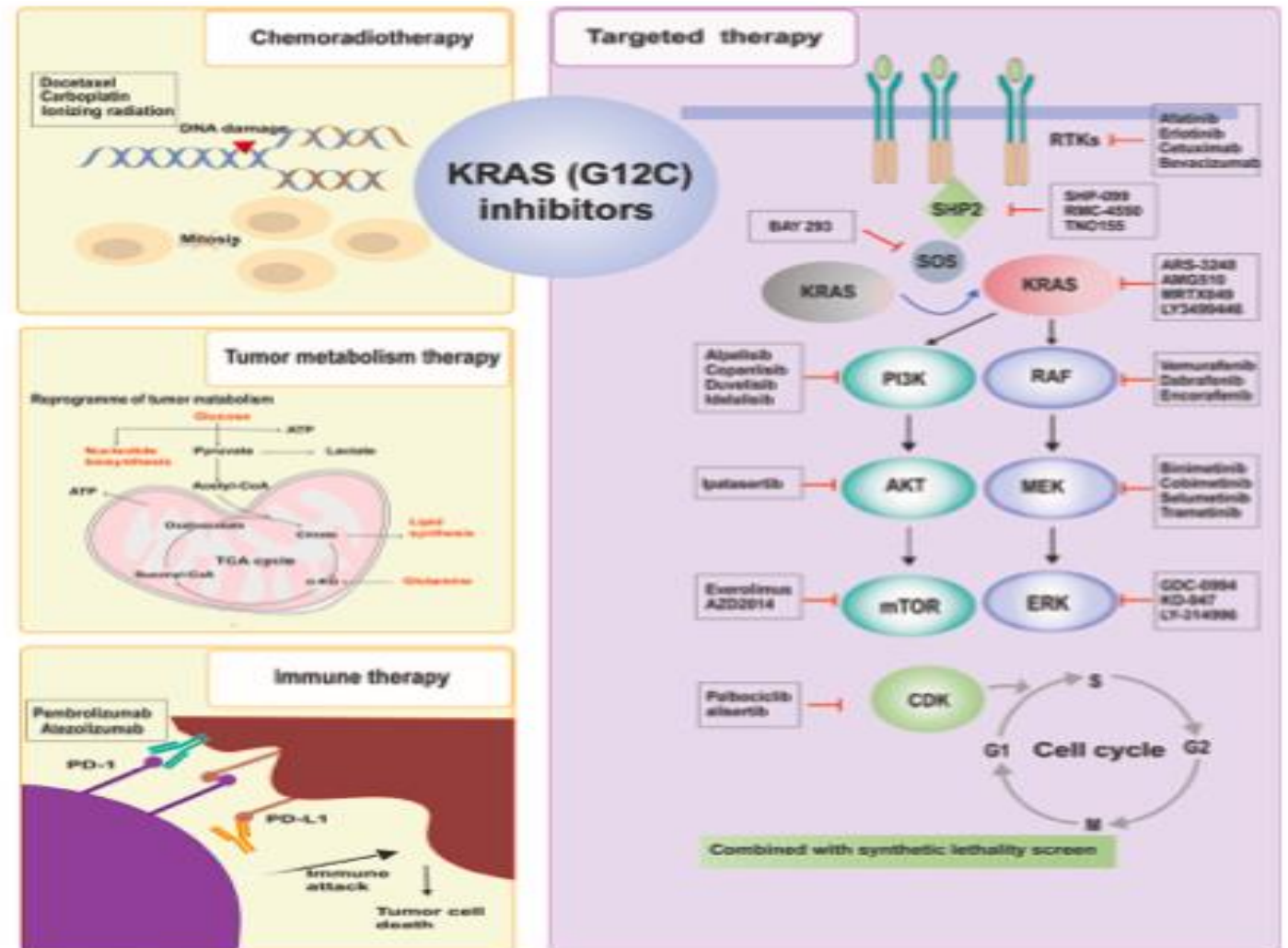


- Response rate was 43% (12/28), including 2 unconfirmed PRs
- SD was observed in 57% (16/28) of patients
- Clinical benefit (DCR) was observed in 100% (28/28) of patients
- No apparent association between response rate and molecular status was shown in an exploratory analysis^e

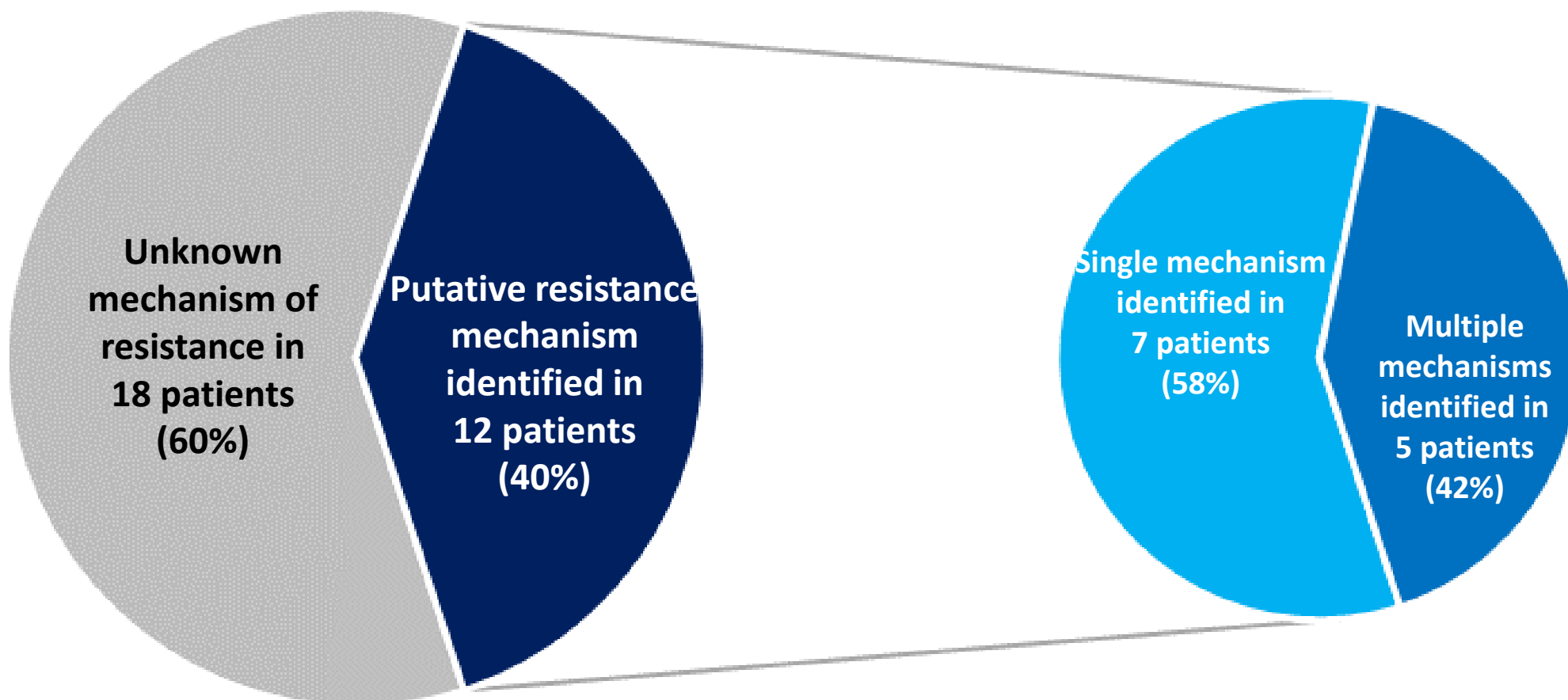
KRAS mutation: from undruggable to druggable in cancer

Lamei Huang¹, Zhixing Guo¹, Fang Wang¹ and Liwu Fu¹✉

Ongoing

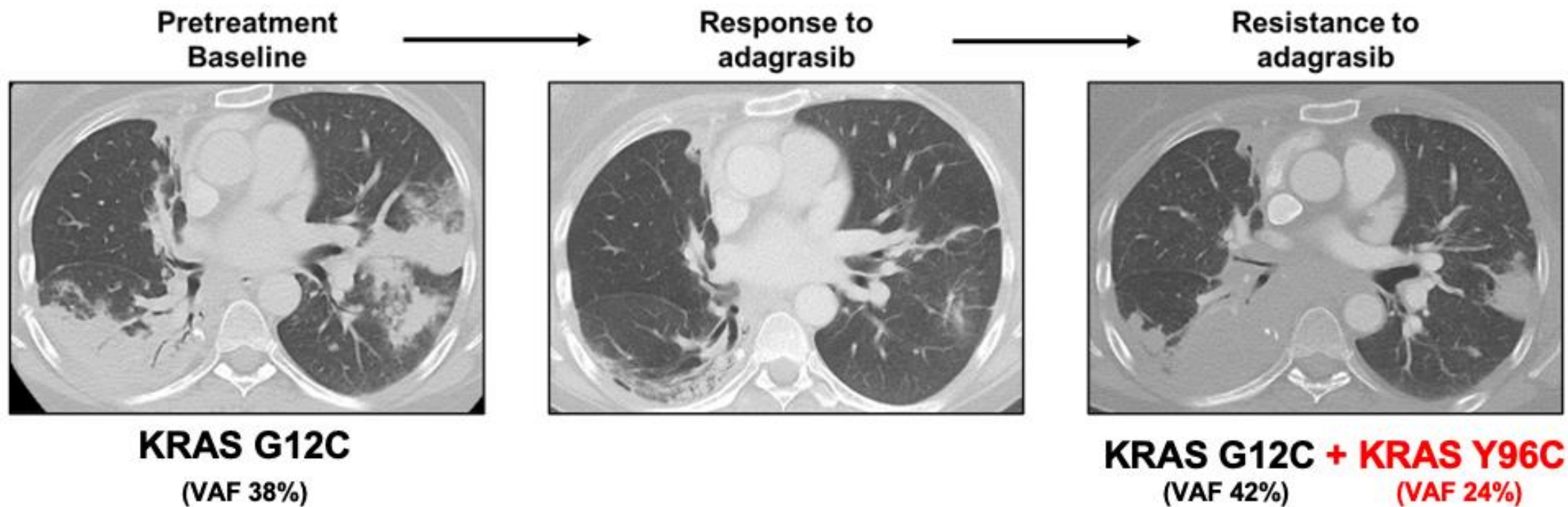


RESISTANCE MECHANISMS



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Novel *KRAS* R68S, H95R/Q/D mutations with multiple concurrent alterations



Additional acquired fusions and MAPK pathway alterations



Secondary *KRAS* mutations in cis/trans



Acquired amplifications in *KRAS* (G12C allele) and *MET*



Histologic transformation

TAKE-HOME MESSAGES

More knowledge, more options.

What RAS mutation, now is a crucial issue in cancer

KRAS G12C: Agnostic molecular alteration

At least two drugs in motion: SOTORASIB and ADAGRASIB

Next year, a major milestone



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