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Plasma levels of soluble TGF β receptor type III: no apparent promise as a marker in acute pancreatitis

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Aim To assess the potential of the soluble transforming growth factor β receptor type III (sTGF β RIII), a key regulator in TGF β signaling, as a biomarker for diagnosis and stratification of patients with acute pancreatitis (AP).

Methods In this small prospective pilot study, patients' (N=22) plasma samples were obtained at three time points: the first and fourth day of hospitalization and the day of hospital discharge. Healthy controls' plasma (N=25) was obtained at a single time point. Concentration of sTGF β RIII in plasma was determined by ELISA. Data were analyzed by fitting linear or linear mixed models.

Results Plasma sTGF β RIII levels at presentation (day 1) were similar in AP patients and healthy participants, irrespectively of the disease severity. sTGF β RIII levels in patients were constant during hospital stay.

Conclusion These observations do not support further evaluation of plasma sTGF β RIII levels in this setting, but do not exclude a potential biological role of TGF β and membrane-bound TGF β RIII in AP pathophysiology.

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Acute pancreatitis (AP) is an inflammatory condition of the pancreas most commonly caused by bile stones or excessive alcohol use (1). It has a wide spectrum of presentations – from mild (most commonly) to life threatening – and may trigger a systemic inflammatory response that could lead to organ dysfunction. An accurate and timely diagnosis and risk stratification are critical for treatment and the optimization of follow-up. This might be of a particular interest in initially milder-to-moderate forms of the disease that could deteriorate over subsequent days (2). Risk stratification in AP is an ongoing challenge considering the limitations of current prognostic scores, which are predominantly based on clinical and radiological findings. Although certain biochemical indicators are essential for diagnosis (serum amylase and lipase), they are without or of limited predictive value (C-reactive protein [CRP], procalcitonin) (2,3). Some cytokines found in plasma, such as interleukin 6 or 8, show promise in severity discrimination, however, they are not routinely used in clinical practice for this indication (4,5).

Transforming growth factor β (TGF β) is a pleiotropic cytokine involved in the regulation of vital cellular processes (eg, maturation and differentiation; cell homeostasis and/or death) (6) as well as in the pathophysiology of malignant diseases, inflammation, and autoimmunity (7-9). TGF β mediates its signaling mainly through TGF β receptor type III (TGF β RIII), a homodimeric co-receptor that facilitates signal transduction by promoting ligands to the type II TGF β receptor without intrinsic kinase activity (6,8). Unlike other TGF β receptors, it is abundantly expressed on almost every human cell type (8,10). TGF β RIII generates, possibly via ectodomain shedding, a soluble form of the receptor (sTGF β RIII) (11-13), a potent TGF β neutralizing agent with a confirmed presence in plasma (14-17). The connection between TGF- β and inflammation is a complex one (6,18). It seemingly involves TGF β RIII, and might be context-dependent, similarly to the role of TGF- β in cancer formation and progression (16,19-22). Generally, TGF β is a strong anti-inflammatory cytokine. Disruption of its signaling results in an increased T-cell response (23), and TGF β RIII has been implicated in Th 17 lymphocyte (CD4+ and CD8+) activation (20,24). In relation to AP specifically, TGF β RIII mRNA was found to be moderately increased in AP tissue samples (25). Taken together, it appears plausible to assume that the plasma levels of the soluble form – sTGF β RIII – might be a biochemical marker in AP. To investigate the feasibility of this hypothesis, we conducted a pilot study in patients with mild-to-moderate AP.

PATIENTS AND METHODS

Study outline

This prospective observational study enrolled consecutive adults diagnosed with a first episode of AP graded as “mild” or “moderate,” admitted between December 10, 2019 and February 18, 2020 at a single tertiary center (University Hospital Dubrava), and a sample of generally healthy volunteers. Patients provided blood samples for sTGF β RIII determination at presentation to the hospital (day 1), day 4 of hospital stay, and at discharge, while healthy participants provided a single blood sample for this purpose. The third time point (discharge day) was purposely chosen not to be a “fixed” day of hospital stay, but rather to represent significant clinical improvement – patients were discharged when the following was achieved: improvement of symptoms or no symptoms reported; adequate oral feeding; and no systemic complications and partial improvement or resolution of local complications. All participants provided a signed informed consent. The study was approved by the Ethics Committee of Dubrava University Hospital.

Participants

All participants had to be free of any other acute or chronic inflammatory disease and have no medical history of malignancy. Acute pancreatitis was diagnosed and classified in line with the revised Atlanta criteria (26), and treatment was in line with the International Association of Pancreatology and American College of Gastroenterology guidelines for the management of AP (27).

sTGF β RIII measurement

Peripheral blood was drawn into citrated Vacutainer tubes (citrate to blood 1:9); plasma was immediately separated by centrifugation (15 minutes at 3000 g) and was kept at -80 °C until analysis. An indirect ELISA kit (Human TGF-beta RIII DuoSet DY242, R&D, Minneapolis, MN, USA) was used to determine the plasma sTGF β RIII expression levels according to the manufacturer’s instructions. All samples and standards were analyzed in duplicates, and the samples with an individual coefficient of variation (CV) greater than 25% were retested in duplicates.

Data analysis

Data are summarized by health status, AP severity, and time point, and were analyzed by fitting linear or lin-

ear mixed models (SAS for Windows 9.4, SAS Inc., Cary, NC, USA). Where required, the variables were transformed to achieve normality of residuals.

RESULTS

A total of 22 AP patients (predominantly biliary AP; 15 mild, 7 moderate AP) and 25 healthy participants were included (Table 1). Plasma sTGF β III levels at presentation (day 1)

were similar in AP patients and healthy participants, irrespective of the disease severity (Table 1, Figure 1A). C-reactive protein levels, serum amylase, lipase, leukocyte counts, and neutrophil-to-lymphocyte ratio gradually decreased until hospital discharge (Table 1), while sTGF β III levels appeared constant over time (Table 1, Figure 1B). There was no association between plasma sTGF β III levels and CRP, leukocyte counts, or neutrophil-to-lymphocyte

TABLE 1. Participants' characteristics at presentation (day 1 or the day of blood sampling for healthy participants), on day 4, and on the day of discharge. Patient data are shown overall and by Atlanta classification of acute pancreatitis (AP) severity. Data are median (Q1-Q3, also range for age and sTGF β III) or count (percent)*

	All patients	Mild AP	Moderate AP	Healthy participants
N	22	15	7	25
Men	13 (59.1)	8 (53.3)	5 (71.4)	15 (60.0)
Age (years)	62 (54-68; 31-79)	61 (44-63; 31-79)	63 (54-75; 53-78)	48 (31-61; 20-80)
Idiopathic AP	2 (9.1)	2 (13.3)	0	—
Alcohol-related AP	4 (18.2)	3 (20.0)	1 (14.3)	—
Biliary AP	15 (68.2)	9 (60.0)	6 (85.7)	—
Hypertriglyceridemia	1 (4.5)	1 (6.7)	0	—
Day 1				
sTGF β III (ng/mL)	89.5 (65.0-103; 5.9-128)	85.5 (59.9-98.5; 5.9-124)	96.6 (77.8-116; 12.5-128)	91.6 (71.9-110; 20.2-128)
Modified Glasgow score	1 (1-1.75)	1 (1-1.25)	1 (1-2)	—
BISAP score				
0	7 (31.8)	6 (40)	1 (14.3)	—
1	8 (36.4)	7 (46.67)	1 (14.3)	—
2	5 (22.7)	1 (6.67)	4 (57.1)	—
3	2 (9.1)	1 (6.67)	1 (14.3)	—
APACHE II score	5 (2.5-7.5)	5 (2-7)	5 (5 - 8)	—
Amylase (IU/L)	595 (357-1687)	753 (514-1700)	411 (276-511)	—
Lipase (IU/L)	1944 (715-2943)	1939 (640-2626)	2336 (1186-3110)	—
CRP (mg/L)	70.4 (8.5-145)	66.3 (4.5-137)	74.5 (50.3-129)	—
Leukocytes (x 10 ⁹ /L)	12.6 (9.6-16.9)	10 (9.6-14.6)	13.9 (11.1-17.2)	—
NLR	8.7 (5.6-15.5)	8.4 (5.62-13.3)	9.5 (8.58-21.4)	—
Day 4				
sTGF β III (ng/mL)	86.3 (69.7-96.2)	77.7 (50-87.5)	101 (91-103)	—
Amylase (IU/L)	89.5 (79.5-165)	92 (79-172)	87 (85-98)	—
Lipase (IU/L)	134 (69-192)	103 (57-190)	198 (166-229)	—
CRP (mg/L)	87 (44-135)	60.6 (22.9-132)	118 (76.1-151)	—
Leukocytes (x 10 ⁹ /L)	8.7 (7.6-11.1)	10.1 (9.6-14.6)	13.9 (11.1-17.2)	—
NLR	5.4 (2.7-6.4)	5.85 (3.47-9.53)	2.72 (1.91-3.29)	—
Discharge (5-13 days post admission, 1 patient day 35)				
sTGF β III (ng/mL)	85.1 (76.7-95.6)	83.3 (70.9-86.6)	99.5 (89.8-104)	—
Amylase (IU/L)	81.5 (73.5-87)	82 (81-87)	75 (72-81)	—
Lipase (IU/L)	66 (53-67)	66 (59.5-66.5)	91 (69.5-113)	—
CRP (mg/L)	20.6 (8.15-41)	22.1 (6.4-49)	22 (16.6-25.5)	—
Leukocytes (x 10 ⁹ /L)	6.6 (5.83-9.35)	6.15 (5.15-7.93)	8.35 (6.4-11.3)	—
NLR	2.92 (2.12-4.54)	3.11 (2.46-4.46)	2.73 (2-7)	—

*Abbreviations: AP – acute pancreatitis; APACHE II – Acute Physiology And Chronic Health Evaluation II; BISAP – bedside index of severity in acute pancreatitis; CRP – C-reactive protein; NLR – neutrophil-to-leukocyte ration; sTGF β III – soluble type III transforming growth factor β receptor.

ratio (not shown). Individual patients' characteristics are available in the [Supplementary Table 1](#).

DISCUSSION

The need for (additional) readily available biochemical markers that would be useful aids to guide treatment and follow-up procedures in AP patients has been well recognized (2,3), and a number of candidates have been suggested to date (3). Biologically, sTGF β RIII appears to be a plausible potential candidate: TGF β and TGF β RIII are known to be involved in inflammatory events, TGF β RIII has been implied specifically in AP (based on tissue expression), and

ectodomain shedding (source of plasma sTGF β RIII) as a part of acute response to noxious stimuli has been documented using transmembrane TGF α as a model (6,20,24,28). The underlying concept implies that noxious stimuli induce the activity of ectodomain sheddases resulting in a release of sTGF β RIII – a process that is upregulated by proinflammatory cytokines (29). The characterization of a reliable biochemical indicator in any setting is a complex time- and resource-consuming task (30); we therefore considered it reasonable to conduct a preliminary evaluation of plasma sTGF β RIII levels “response” to milder forms of AP (where a “signal” would indicate the feasibility of a more extensive evaluation). We observed no difference in sTGF β RIII levels

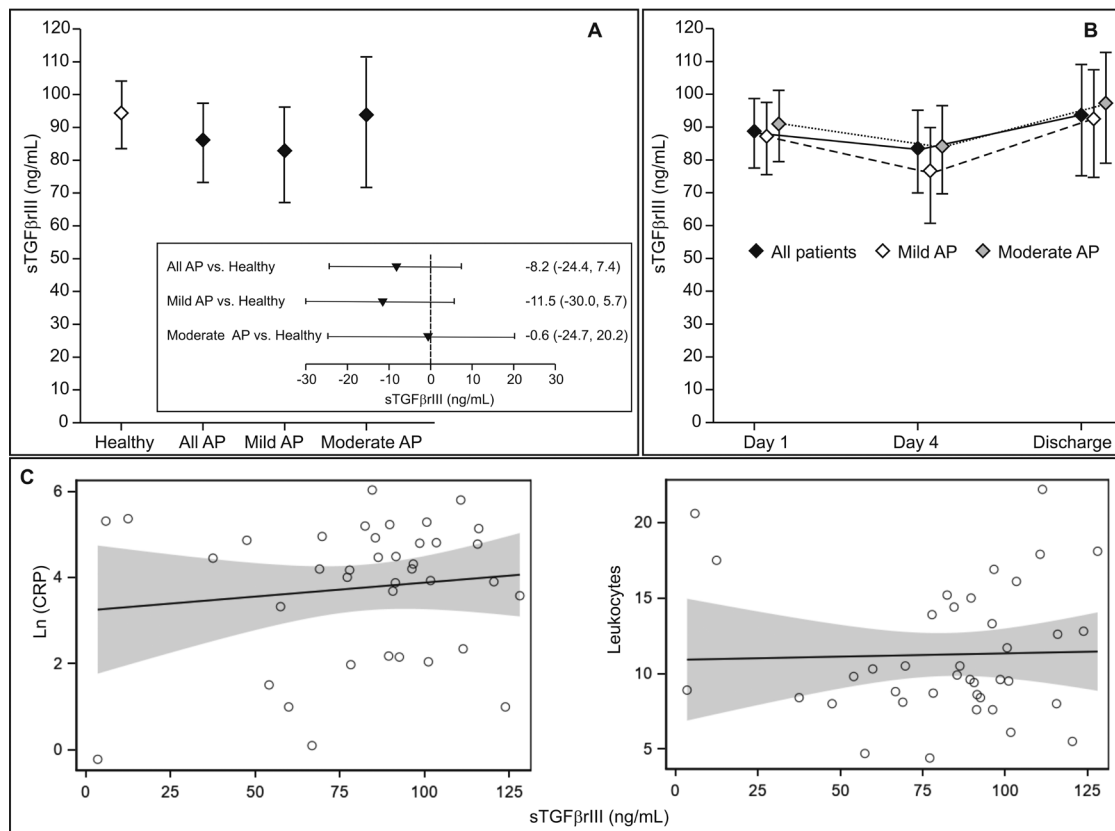


FIGURE 1. (A) Age and sex-adjusted mean (95% confidence interval, CI) plasma soluble type III transforming growth factor β receptor (sTGF β RIII) levels in healthy participants and patients with acute pancreatitis (AP) (overall and by severity classified in line with the revised Atlanta criteria). The insert depicts adjusted differences between participants, with 95% CIs. A general linear model (effects: age, sex, health condition) was fitted to sTGF β RIII levels to generate adjusted means and mean differences. **(B)** Adjusted sTGF β RIII levels (mean, 95% CI) in AP patients over the observed period (overall and by severity). A mixed model (fixed effects: age, sex, time, disease severity and time*severity interaction) was fitted to sTGF β RIII. **(C)** Relationship between plasma sTGF β RIII levels and C-reactive protein (left) or leukocyte counts (right). A separate mixed model (fixed effects: age, sex, time, sTGF β RIII, time* sTGF β RIII interaction) was fitted to (ln) C-reactive protein and leukocyte count to generate depicted adjusted regression lines (shaded area: 95% CIs). The same analysis was conducted with serum lipases and neutrophil-to-lymphocyte ratio (not shown), also showing no association with sTGF β RIII.

between the affected patients at presentation and their healthy peers, no obvious dynamics in sTGF β RIII level over the course of the disease, and no relationship between sTGF β RIII and other routinely used indicators of tissue damage (enzymes) or inflammation (no indication of concurrent validity). These observations do not support further evaluation of plasma sTGF β RIII levels in this setting, but do not exclude a potential biological role of TGF β and membrane-bound TGF β RIII in AP pathophysiology. The present observations might be a result of a number of possible underlying mechanisms, such as eg, formation of TGF β -sTGF β RIII complexes that may not be detected by ELISA assays or the escape of the membrane-bound TGF β RIII from ectodomain shedding due to involvement in the tissue repair processes (31). It is also possible that the relationship of TGF β RIII with inflammation is more closely related to the chronic inflammatory processes as observed in cancer at the systemic level (16,32).

Overall, although limited by a small single-center sample, the present study does not support further evaluation of plasma sTGF β RIII levels as a potential diagnostic/prognostic aid in acute pancreatitis.

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Ethical approval The study was approved by the Ethics Committee of Dubrava University Hospital (2019/1610-11).

Declaration of authorship GS, MZ, IG, and LG conceived and designed the study; GS, MZ, SH, and JB acquired the data; GS, VT, RN, and LG analyzed and interpreted the data; GS, SH, and JB drafted the manuscript; MZ, VT, IG, RN, and LG critically revised the manuscript for important intellectual content; all authors gave approval of the version to be submitted; all authors agree to be accountable for all aspects of the work.

Competing interests All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: no support from any organization for the submitted work; no financial relationships with any organizations that might have an interest in the submitted work in the previous 3 years; no other relationships or activities that could appear to have influenced the submitted work.

References

- Wang G-J, Gao C-F, Wei D, Wang C, Ding S-Q. Acute pancreatitis: etiology and common pathogenesis. *World J Gastroenterol*. 2009;15:1427-30. [Medline:19322914](#) [doi:10.3748/wjg.15.1427](#)
- Meher S, Mishra TS, Sasmal PK, Rath S, Sharma R, Rout B, et al. Role of biomarkers in diagnosis and prognostic evaluation of acute pancreatitis. Jansen EHJM, editor. *J Biomarkers [Internet]*. 2015;2015:519534.
- Silva-Vaz P, Abrantes AM, Castelo-Branco M, Gouveia A, Botelho MF, Tralhão JG. Multifactorial scores and biomarkers of prognosis of acute pancreatitis: Applications to research and practice. *Int J Mol Sci*. 2020;21:1-26. [Medline:31947993](#) [doi:10.3390/ijms21010338](#)
- Wu BU. Prognosis in acute pancreatitis. *CMAJ*. 2011;183:673-7. [Medline:21422134](#) [doi:10.1503/cmaj.101433](#)
- Papachristou GI, Whitcomb DC. Inflammatory markers of disease severity in acute pancreatitis. *Clin Lab Med*. 2005;25:17-37. [Medline:15749230](#) [doi:10.1016/j.cll.2004.12.003](#)
- Tzavlaki K, Moustakas A. TGF- β signaling. *Biomolecules*. 2020;1-38. [Medline:32210029](#) [doi:10.3390/biom10030487](#)
- Chen W, Wahl SM. Manipulation of TGF-beta to control autoimmune and chronic inflammatory diseases. *Microbes Infect*. 1999;1:1367-80. [Medline:10611763](#) [doi:10.1016/S1286-4579\(99\)00249-X](#)
- Gatza CE, Oh SY, Blobe GC. Roles for the type III TGF- β receptor in human cancer. *Cell Signal*. 2010;22:1163-74. [Medline:20153821](#) [doi:10.1016/j.cellsig.2010.01.016](#)
- Buck MB, Knabbe C. TGF-beta signaling in breast cancer. *Ann N Y Acad Sci*. 2006;1089:119-26. [Medline:17261761](#) [doi:10.1196/annals.1386.024](#)
- Huang JJ, Corona AL, Dunn BP, Cai EM, Prakken JN, Blobe GC. Increased type III TGF- β receptor shedding decreases tumorigenesis through induction of epithelial-to-mesenchymal transition. *Oncogene*. 2019;38:3402-14. [Medline:30643193](#) [doi:10.1038/s41388-018-0672-7](#)
- Bandyopadhyay A, López-Casillas F, Malik SN, Montiel JL, Mendoza V, Yang J, et al. Antitumor activity of a recombinant soluble betaglycan in human breast cancer xenograft. *Cancer Res*. 2002;62:4690-5. [Medline:12183427](#)
- Andres JL, Stanley K, Cheifetz S, Massague J. Membrane-anchored and soluble forms of betaglycan, a polymorphic proteoglycan that binds transforming growth factor- β . *J Cell Biol*. 1989;109:3137-45. [Medline:2592419](#) [doi:10.1083/jcb.109.6.3137](#)
- López-Casillas F, Cheifetz S, Doody J, Andres JL, Lane WS, Massagué J. Structure and expression of the membrane proteoglycan betaglycan, a component of the TGF-beta receptor system. *Cell*. 1991;67:785-95. [Medline:1657406](#) [doi:10.1016/0092-8674\(91\)90073-8](#)
- Esparza-Lopez J, Montiel JL, Vilchis-Landeros MM, Okadome T, Miyazono K, López-Casillas F. Ligand binding and functional properties of betaglycan, a co-receptor of the transforming growth factor-beta superfamily. Specialized binding regions for transforming growth factor-beta and inhibin A. *J Biol Chem*. 2001;276:14588-96. [Medline:11278442](#) [doi:10.1074/jbc.M008866200](#)
- Vilchis-Landeros MM, Montiel JL, Mendoza V, Mendoza-Hernández G, López-Casillas F. Recombinant soluble betaglycan is a potent and isoform-selective transforming growth factor-beta neutralizing agent. *Biochem J*. 2001;355:215-22. [Medline:11256966](#)

- doi:10.1042/bj3550215
- 16 Grgurevic L, Novak R, Trkulja V, Hrkac S, Salai G, Bilandzic J, et al. Plasma levels and tissue expression of soluble tgfbriii receptor in women with early-stage breast cancer and in healthy women: a prospective observational study. *J Transl Med.* 2020. [Medline:33308241](#) doi:10.1186/s12967-020-02659-4
- 17 Jurisic D, Erjavec I, Trkulja V, Dumic-Cule I, Hadzibegovic I, Kovacevic L, et al. Soluble type III TGF β receptor in diagnosis and follow-up of patients with breast cancer. *Growth Factors.* 2015;33:200-9. [Medline:26190421](#)
- 18 Yoshimura A, Wakabayashi Y, Mori T. Cellular and molecular basis for the regulation of inflammation by TGF-beta. *J Biochem.* 2010;147:781-92. [Medline:20410014](#) doi:10.1093/jb/mvq043
- 19 Huang JJ, Blobel GC. Dichotomous roles of TGF- β in human cancer. *Biochem Soc Trans.* 2016;44:1141-454. [Medline:27911726](#) doi:10.1042/BST20160065
- 20 Barry RJ. Investigating the immunoregulatory role of betaglycan. A thesis submitted to the University of Birmingham for the degree of Academic Unit of Ophthalmology. 2015;(August).
- 21 Gordon KJ, Dong M, Chislock EM, Fields TA, Blobel GC. Loss of type III transforming growth factor beta receptor expression increases motility and invasiveness associated with epithelial to mesenchymal transition during pancreatic cancer progression. *Carcinogenesis.* 2008;29:252-62. [Medline:17999987](#) doi:10.1093/carcin/bgm249
- 22 Nixon AB, Pang H, Starr MD, Friedman PN, Bertagnolli MM, Kindler HL, et al. Prognostic and predictive blood-based biomarkers in patients with advanced pancreatic cancer: results from CALGB80303 (Alliance). *Clin Cancer Res.* 2013;19:6957-66. [Medline:24097873](#) doi:10.1158/1078-0432.CCR-13-0926
- 23 Hong S, Lee H, Kim SJ, Hahn K. Connection between inflammation and carcinogenesis in gastrointestinal tract: Focus on TGF- β signaling. 2010;16:2080-93.
- 24 Chen Y, Yang P, Li F, Hou S, Jiang Z, Shu Q, et al. Association analysis of TGFBR3 gene with Vogt-Koyanagi-Harada disease and Behcet's disease in the Chinese Han population. *Curr Eye Res.* 2012;37:312-7. [Medline:22440163](#) doi:10.3109/02713683.2011.635398
- 25 Friess H, Lu Z, Riesle E, Uhl W, Bründler AM, Horvath L, et al. Enhanced expression of TGF- β s and their receptors in human acute pancreatitis. *Ann Surg.* 1998;227:95-104. [Medline:9445116](#) doi:10.1097/0000658-199801000-00014
- 26 Banks PA, Bollen TL, Dervenis C, Gooszen HG, Johnson CD, Sarr MG, et al. Classification of acute pancreatitis—2012: revision of the Atlanta classification and definitions by international consensus. *Gut.* 2013;62:102-11. Internet. [Medline:23100216](#) doi:10.1136/gutjnl-2012-302779
- 27 IAP/APA evidence-based guidelines for the management of acute pancreatitis. *Pancreatol.* 2013;13(4 Suppl 2):e1-15. [Medline:24054878](#) doi:10.1016/j.pan.2013.07.063
- 28 Stewart AG, Thomas B, Koff J. TGF- β : Master regulator of inflammation and fibrosis. *Respirology.* 2018;23:1096-7. [Medline:30284753](#) doi:10.1111/resp.13415
- 29 Hayashida K, Bartlett AH, Chen Y, Park PW. Molecular and cellular mechanisms of ectodomain shedding. *Anat Rec (Hoboken).* 2010;293:925-37. [Medline:20503387](#) doi:10.1002/ar.20757
- 30 Strimbu K, Tavel JA. What are biomarkers? *Curr Opin HIV AIDS.* 2010;5:463-6. [Medline:20978388](#) doi:10.1097/COH.0b013e32833ed177
- 31 Eslami A, Gallant-Behm CL, Hart DA, Wiebe C, Honardoust D, Gardner H, et al. Expression of integrin alphavbeta6 and TGF-beta in scarless vs scar-forming wound healing. *J Histochem Cytochem.* 2009;57:543-57. [Medline:19223298](#) doi:10.1369/jhc.2009.952572
- 32 Gordon KJ, Dong M, Chislock EM, Fields TA, Blobel GC. Loss of type III transforming growth factor β receptor expression increases motility and invasiveness associated with epithelial to mesenchymal transition during pancreatic cancer progression. *Carcinogenesis.* 2008;29:252-62. [Medline:17999987](#) doi:10.1093/carcin/bgm249